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EDGEWOOD ARSENAL
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EASP 300-4

History of Research and Development of the Chemical Warfare Service Through 1945

ANTIGAS COLLECTIVE PROTECTION EQUIPMENT

by

Allan L. West
Joseph Goldfield
James Mitchell

December 1969

DEPARTMENT OF THE ARMY
EDGEWOOD ARSENAL
Defense Development and Engineering Laboratories
Edgewood Arsenal, Maryland 21010

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FOREWORD

The work described in this report was guided by the requirements set forth in the memorandum dated 1 August 1944, ASF, SPROD, subject: History of wartime Research and Development. This report was focused particularly on the work done from July 1940 to December 1945.

Acknowledgments

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History of Research and Development of the Chemical Warfare Service Through 1945

ANTIGAS COLLECTIVE PROTECTION EQUIPMENT

I. HISTORICAL BACKGROUND.

A. Research and Development of Collective Protection Equipment During World War I.

During the first world war, the problem of antigas collective protection was recognized by all of the major belligerents. After they had been subjected to a sustained gas attack, the troops wearing individual antigas protective equipment in the trenches were not in top condition for repelling an infantry assault. The high air resistance of the gas masks worn sapped their strength; therefore, provision had to be made to permit a portion of the men to rest in a gasproof dugout where masks did not have to be used, thus conserving their fighting abilities.

All of the major powers used similar methods to protect their dugouts. The French, however, seem to have gone further in this direction than any of the others. For example, a typical French pamphlet issued as early as 1916 described the following methods for gasproofing a dugout: (1) close all openings; (2) hang two impregnated curtains with several feet between them at the entrance; (3) spray atomized chemical solution to reduce gas concentration; (4) build hot fires in front of and behind the trenches to cause the gas to rise; and (5) build fires in the trenches to drive out gases. This pamphlet proposed using compressed air, oxygen tanks, chemical reactions releasing oxygen, or "drawing contaminated air through a layer of earth containing organic matter" in order to replace the oxygen breathed by the troops in the dugouts. The last suggestion was the first reference found to anything like our modern conception of a collective protector.*

A year later the French published details of two methods of dugout protection that resemble our present trends. These were: (1) the Lapicque process that made use of strained humus, leaving the soil filling an opening in a dugout and using a fan for drawing air through; and (2) the Leclerg process that used a filter box containing a chemical and a fan mounted on the box for drawing purified air through the chemical bed. The assembly could deliver about 53 cu ft of purified air per minute (figures 1 and 2).[1]

The French had advanced so far in their consideration of antigas protective devices that they even discussed the protection of tanks from gas penetration. They concluded that since their currently-used tank models did not lend themselves readily to gas proofing, they would have to shelf the idea.**

Toward the end of the war, French scientists published a paper in which numerous experiments, test methods, and apparatus were described for the development of a suitable collective protector.

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*Notice Au Suject de la Protection Contre Les Gaz Asphyxiants. (Note on the Subject of Protection Against war Gases.) 1916.

**Lus La Protection du Personnel des Chars d'Assaut. (The Protection of Tank Personnel.) Secretarist Permanent Interallie' de Services d' Etudes des Gaz de Combat. (Permanent Interallied Committee of the Service for the Study of War Gases.) Oct 1918.

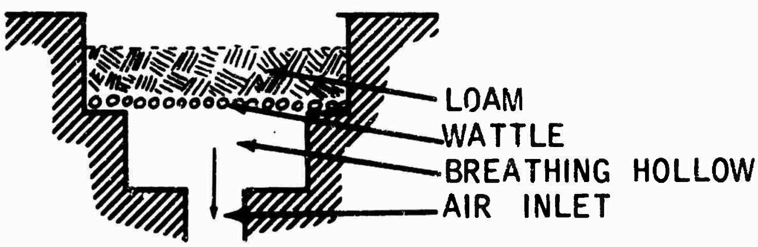


Figure 1. Plant Material Filters

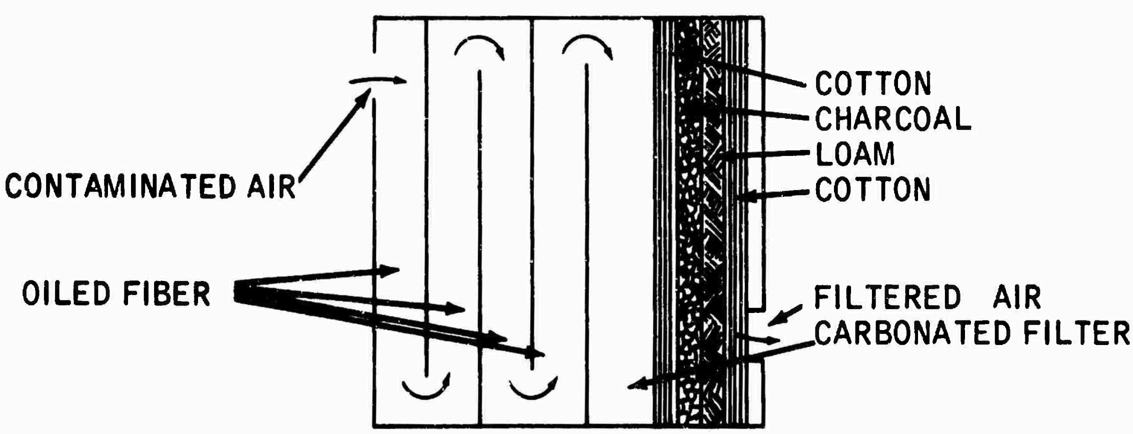


Figure 2. Scheme of the Filter Layers

The best results were obtained with a box filled with sawdust soaked in an anthracene oil. Flows as high as 300 cu ft/min of contaminated air were purified satisfactorily.*

The English also must have worked on collective protectors during the war. Toward the end of the war, the British Central Laboratory described two air filtering units (collective protectors) that used hand-driven pumps for sucking air through an adsorbent bed that was set vertical with the hand-driven pump on top. This unit purified 2000 cu ft of air per hour. A larger unit, which could deliver 7000 cu ft of purified air per hour, had a horizontal adsorbent bed with the hand-driven pump on the side. Figures 3 and 4 show the construction of these units.[2]

No evidence could be found that the Germans, the Americans, or the Russians used collective protectors or did any work on them in the first world war.

B. Research and Development of Collective Protectors During the Period 1920 Through 1940.

Since the last war, evidence could be found in abundance that every major power had worked on collective protectors. Although the information gathered during this period was only fragmentary, probably because of the military secrecy that shrouded such developments, documents and equipment captured on the battlefields showed that the Germans, the Japanese, the Italians, and the French, as well as ourselves, had developed collective protectors.

From 1920 to 1940, our only sources of information about collective protectors were intelligence reports and published references. It was true that these sources probably did not reveal the latest developments, but they indicated that thought and effort was being applied in that direction.

In a textbook on military chemistry, the Russians published information which indicated that they were devoting considerable thought to collective protection (figures 5, 6, and 7). Figure 5 shows a ventilated Russian shelter. Figure 6 is a sketch of their adsorbing filter F-P-M-60, with a hand-operated pump. A filter made of a layer of humus bearing soil, a layer of charcoal, and a straw bed on a support of poles and twigs is shown in figure 7.[3]

The Germans offered a collective protector for sale, presumably to civilians.[4] Their close attention to foreign developments and their own ideas on the subject of collective protection were shown in standard military texts.[5]

The French, always in the forefront in gas defense, invited one of our military attaches to a demonstration of a gasproof metro station. A space 500 m long was blocked off, 300 m had the cross section of our own double-tracked subway tube, while the remainder had the cross-sectional area of a subway station. Air purifying units capable of supplying 8000 cu m of air per hour were provided in a special pump room. The air was distributed throughout the protected area by a duct system. Installed in the station entrance were three

*Essais D' Epuration Chemique Pour la Protection des Abis Contre les Gaz Toxiques. Extrait du Procés Verbal de la Section de Protection de la Leance du Mai 1918.

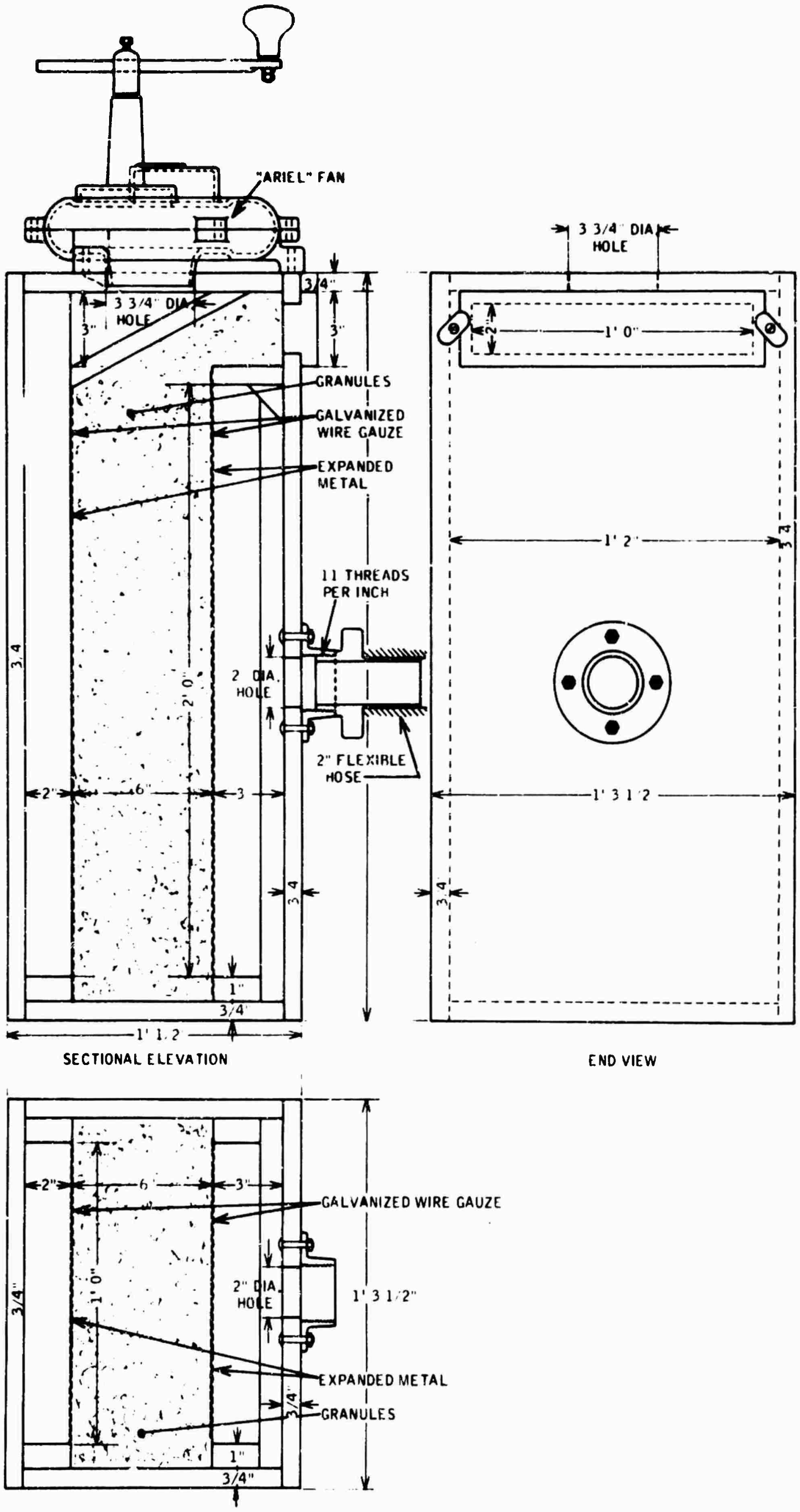


Figure 3. Filter for Hand-Driven Fan Having Delivery of 2000 cu ft/hr

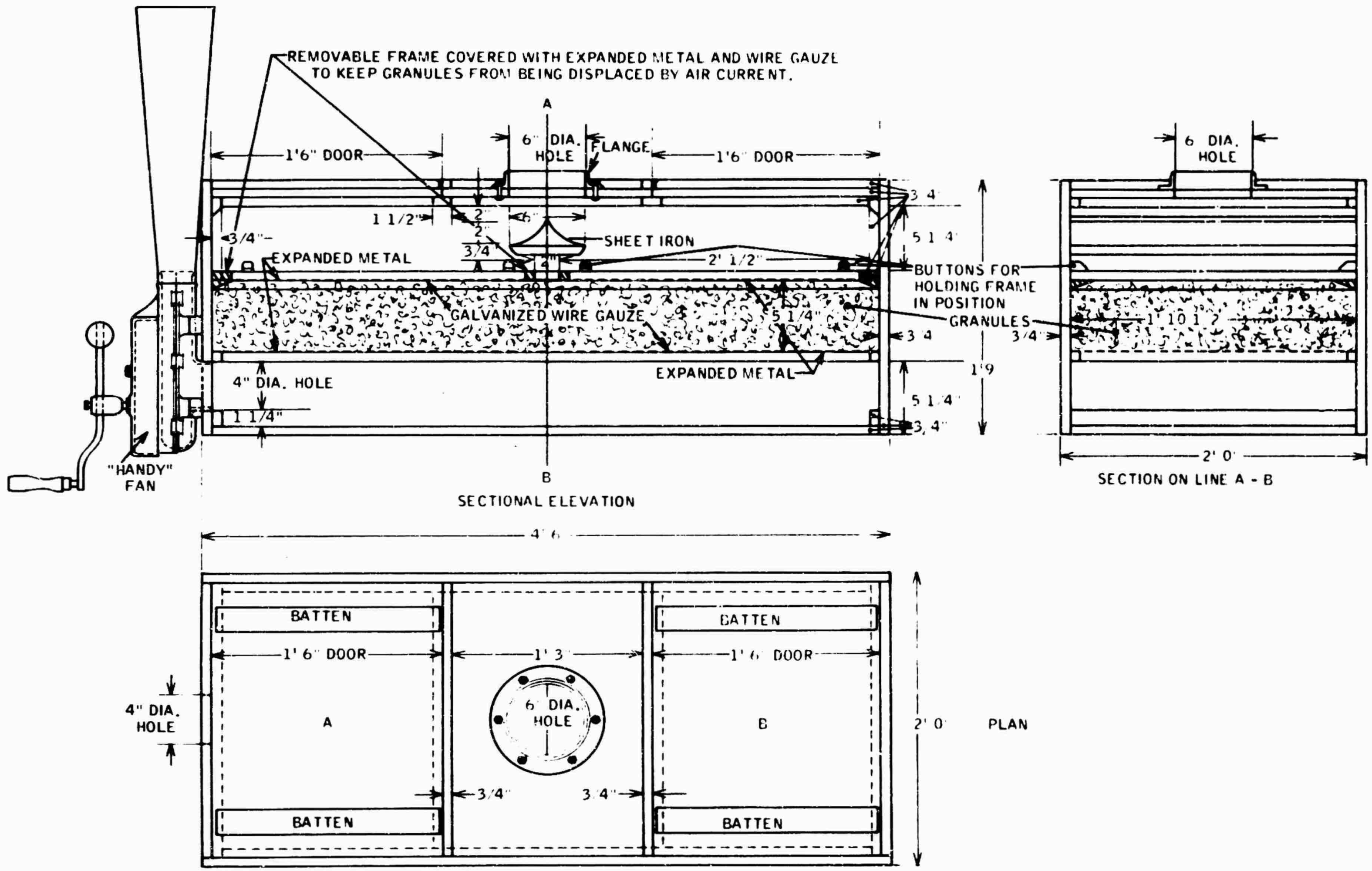


Figure 4. Filter for Hand-Driven Fan Having Delivery of 7000 cu ft/hr

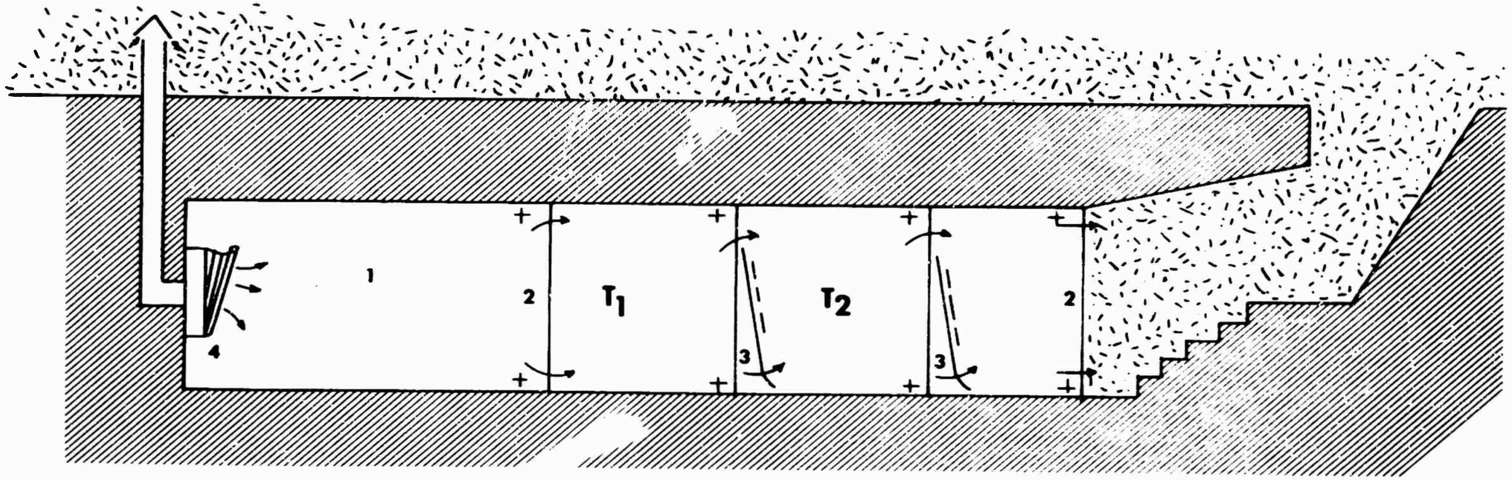


Figure 5. Plan of Ventilation Shelter

(1) Shelter: T_1 and T_2, the drums; (2) doors; (3) impermeable curtains; and (4) air filter.

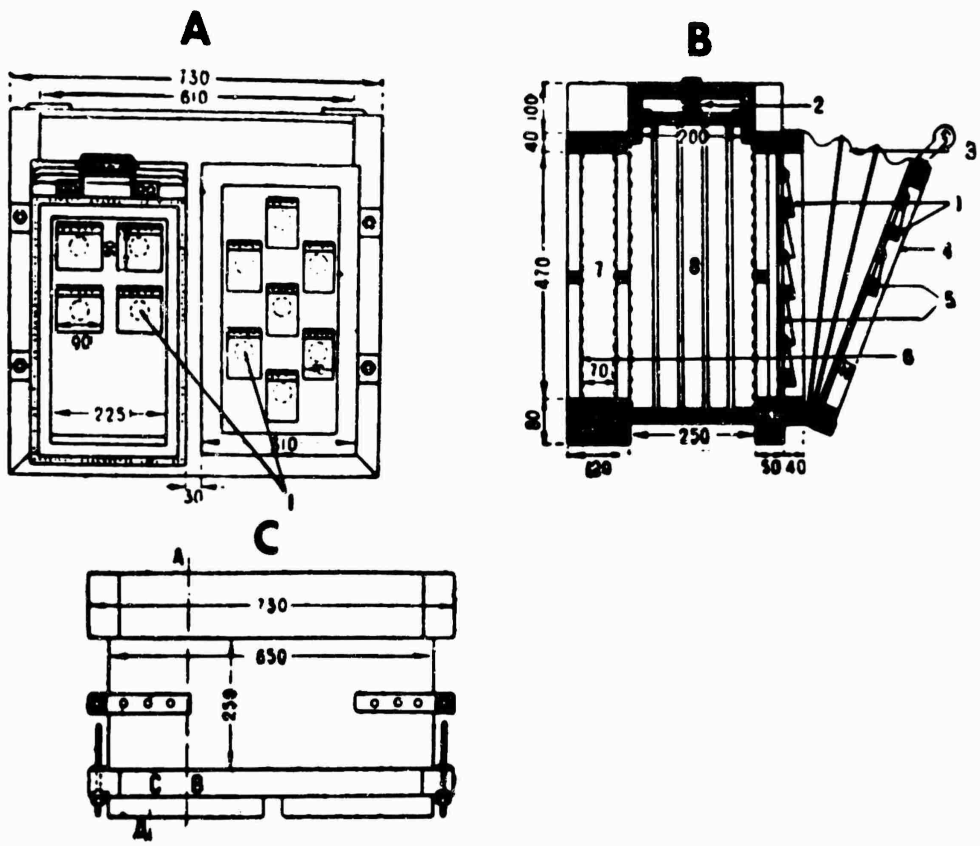


Figure 6. Filter-Absorber (Type F-P-M-60) for Shelter

A. View of filter-absorber with right movable flap board removed.

B. Section along ABCD: (1) flaps; (2) spring; (3) bellows; (4) movable flap board; (5) plywood; (6) nets; (7) filter material; and (8) absorbing mass.

C. View from above (bellows removed).

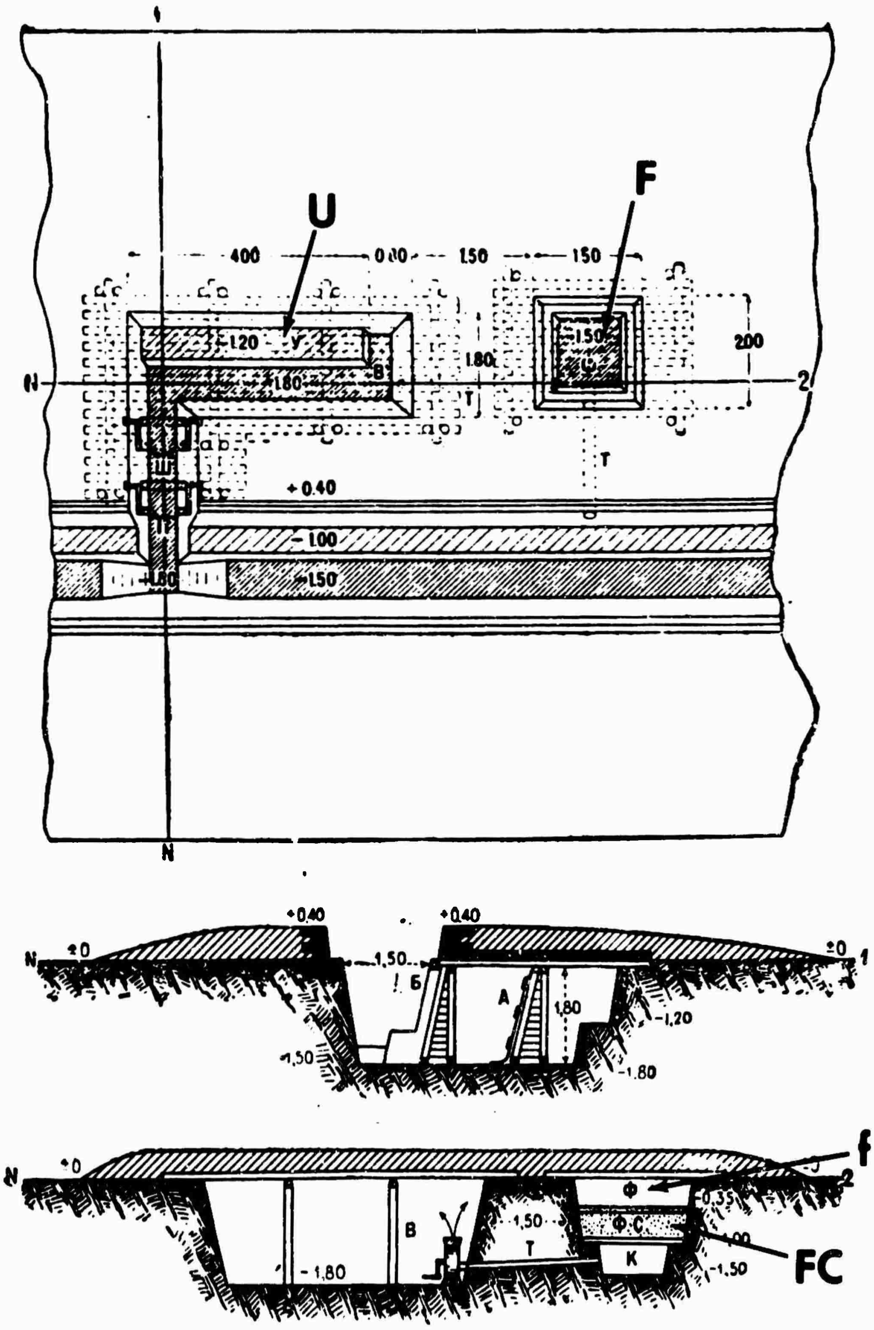


Figure 7. Light Shelter with Air Filter of Vegetable Earth and Charcoal

Top View: II, Entrance; III, drum; U, shelter; B, ventilator, T, pipe bringing in air; and F, air filter.

A. Curtains let down; b, curtain on rack raised; FC, layer of filter; f, chamber over filter where poisoned air enters; K, room where air is pure from poisons; T, tube conduit to shelter; and B, ventilator.

sets of doors which were so hinged as to permit air to escape and relieve any excess pressure that built up in the enclosure. The doors thus provided formed two sets of air locks.*

An Italian company built a collective protector capable of delivering 60 cu m of purified air per hour or of recirculating and regenerating 30 cu m of air per hour. This protector was installed in a number of their military and naval installations. The equipment was offered for sale to the United States Government by the firm that constructed it.**

The British, it appeared, did not like the idea of special pieces of equipment for collective protection. They felt that a suitable number of gas-mask canisters in a special filter unit would solve their problem more cheaply and expediently. Their system of using gas-mask canisters in air filters had been installed on their ships and they felt they were adequate.[6]

The earliest reference that could be found concerning the interest of the United States Army in collective protectors was in a letter from the office of the chief of the Chemical Warfare Service discussing the protection of permanent fortifications.† On the basis of this correspondence Project D1.3-5c, Protection of Permanent Fortifications was initiated in October 1924.

In January 1926, the Chemical Warfare Officer, Philippine Department, improvised a collective protector by connecting a number of gas-mask canisters in parallel and drawing air through the assembly with a Sirocco blower driven by a 1/10-hp motor (figure 8). The capacity was 12.5 cu ft of air per minute. This same officer also proposed an alternate improvisation consisting of a 40-gal drum filled with a liquid absorbent plus a means of bubbling air through the liquid.[7,8]

During 1926, an article appeared in the transactions of the American Institute of Chemical Engineers that discussed the theory of collective protection and showed a model of a protected dugout equipped with a collective protector. This dugout is shown in figure 9.[9]

The basic design that has been used in most American collective protectors was described in a report in 1927. The fundamental unit was scaled-up Mk III gas-mask canister. It consisted of a round, perforated-metal tube 2 ft 6 in. long, which was surrounded by a layer of charcoal granules held in place by a second perforated-metal tube concentric with the first inner tube. Around the outer tube was wrapped the filter material. The outside diameter of the completed unit was about 4-1/2 in. Two sizes were fabricated, 4-1/2 in. by 2 ft 6 in. and a larger one, 6 in. by 6 ft. The E1R20 Collective Protector was an assembly of four of the 4-1/2-in. by 2-ft 6-in. tubes in a canister assembly with a hand-operated blower for moving air through. The capacity was 50 cu ft of air per minute (figure 10).[10]

In 1927 a model of the E1R20 Collective Protector assembly E15 (figure 11) composed of 16- to 30-in.-long tubes, arranged in parallel in a container, was installed in a plotting room at Battery De Russy, Fort Monroe, Virginia. It was felt that in a gas attack, plotting-room personnel would be most severely handicapped if they had to wear gas masks.[8] The permanent installation was tested maintaining a tear-gas smoke cloud around the outside

*Gas Protection of Metro Stations. Paris Report. French Military Attache'. May 1933. (In TSD Tech Lib as ETF 550F-74.)

**American Naval Attache. Report. 12 Oct 1939.

†Chemical Warfare Service. Letter, 400.112/147, Office of the Chief, CWS. 5 June 1922.

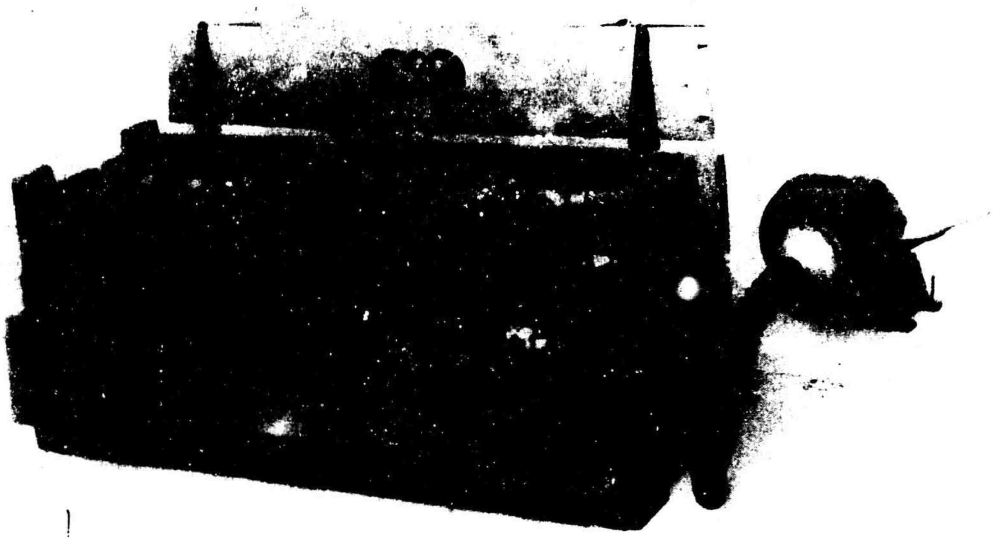


Figure 8. Collective Protector E3R1

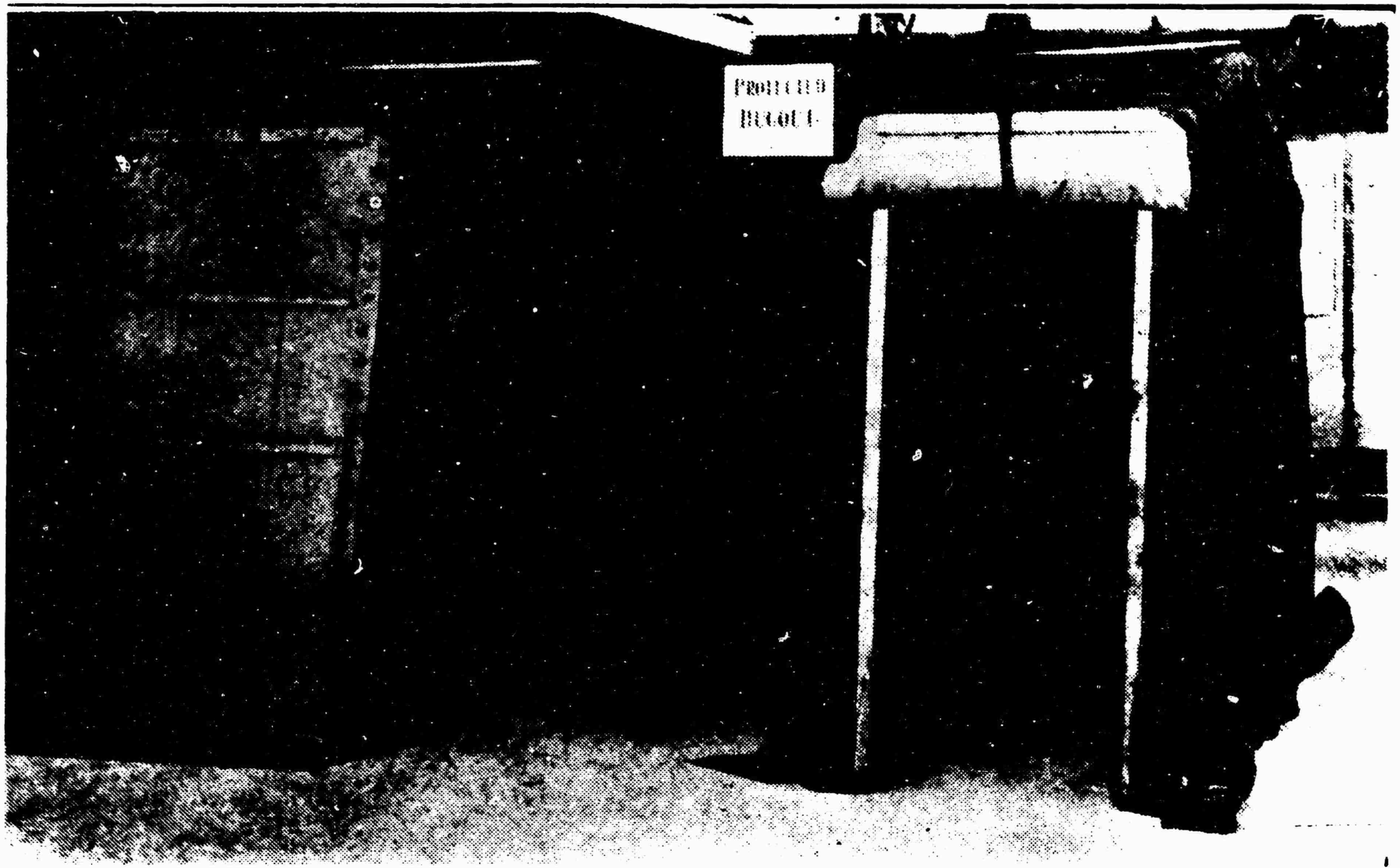


Figure 9. A Dugout Model for Instruction Purposes

Figure 10. Collective Protector, Portabie, for Dugouts

Showing Collective Protector E1R20 Four Unit Assembly E5 including forge hand blower, carrying harness and air hose.

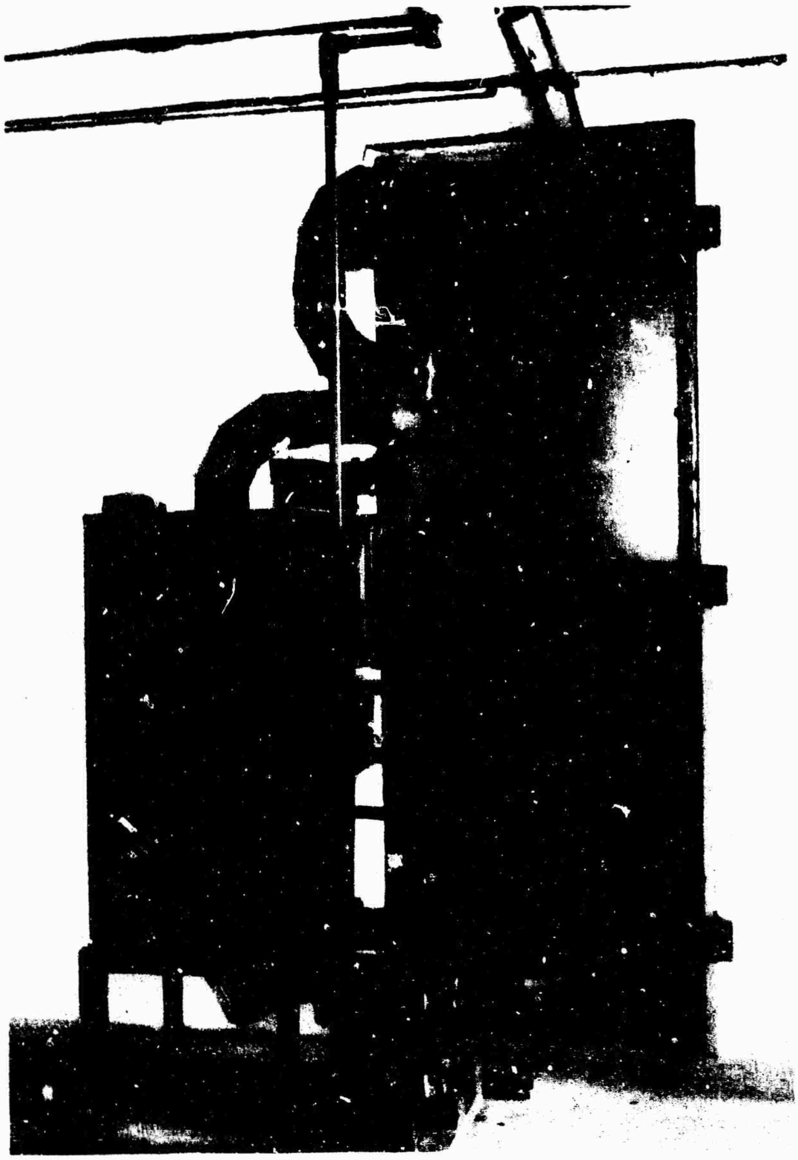


Figure 11. Collective Protector (E1R20) Sixteen Unit Assembly (E15)
Showing motor, blower, and container assembly in position in corridor adjacent plotting room.

of the plotting room. Although 22 people and an oil stove which was in operation were in the room, no gas was noticed and the people were comfortable.[11] The Coast Artillery Board was satisfied with the protection afforded by the collective protector and recommended its adoption as standard.[12]

Although the Coast Artillery Board was well satisfied with the collective protector installation, a question arose concerning the financing of the venture. The installation was quite expensive, relative to peacetime US Army allotments. The Adjutant General's Office was consulted and they initiated a policy by which the installation of antigas collective protection was to be guided. The military bases in outlying possessions of the United States were to be protected first and, because of the lack of funds, provision would have to be made for emergency improvised protection[13] rather than permanent antigas protection.

Following a number of minor modifications to permit ease of manufacture and improvement to some features of the design, the collective protector was officially standardized as the M1 Collective Protector on 15 July 1932 (figure 12). The M1 Collective Protector has since been superseded by the M1A1 and M1A2 Collective Protectors. The M1A1 Collective Protector simply had a different valve system and the M1A2 Collective Protector dispensed with the airblast. The net weight of the M1 Collective Protector was 1210 lb. It delivered 200 cu ft of air per minute against a back pressure of 0.1 in. of water. The gas protection and smoke protection were the same as the standard service gas-mask canister.[14]

Some work on collective protection equipment for use on ships had been done during this period by the Chemical Warfare Service. In general, the collective protectors proposed were very similar to those used for fortification protection. Figures 13 and 14 show views of the E1R22 Collective Protector Assembly M2, which was the one proposed and tested for use aboard ship.[15] An alternate method for the use of a collective protector was also proposed. It consisted of an inlet pipe for the ventilating system placed as high as possible above the ship's deck. The main defect of this system was that a gas cloud high enough to cover the inlet pipe would render the system inoperative and, in fact, dangerous; however, its simplicity and low cost were points in its favor.[16]

In 1932 the subject of tank protection was discussed in an interchange of letters between the Infantry Board and the Chemical Warfare Service. It was suggested that tanks should be made airtight and air or oxygen supplied to the crew members from compressed air or oxygen cylinders. The relative advantages of this system of protection versus the installation of an air-purifying collective protector were discussed in the second indorsement to the correspondence. The oxygen system was ruled out because of the fire hazard, and the compressed air cylinder and collective protector system were compared. It was concluded that the collective protector system was greatly superior to the compressed air cylinder. As far as could be ascertained, this correspondence did not lead to any experimental work during this period.*

A collective protector that could be used in the field was needed. The M1 Collective Protector, weighing over 1200 lb, did not have the mobility required for a piece of field equipment. As a first effort, the M1 Collective Protector was stripped of nonessential parts to reduce it to the lowest possible weight. The results of this work were the development of the

*Chemical Warfare Service. Letter, 2nd Wrapper Ind. 470.8/6, from Headquarters, Edgewood Arsenal, Maryland, to Chief, CWS. 28 Nov 1932.

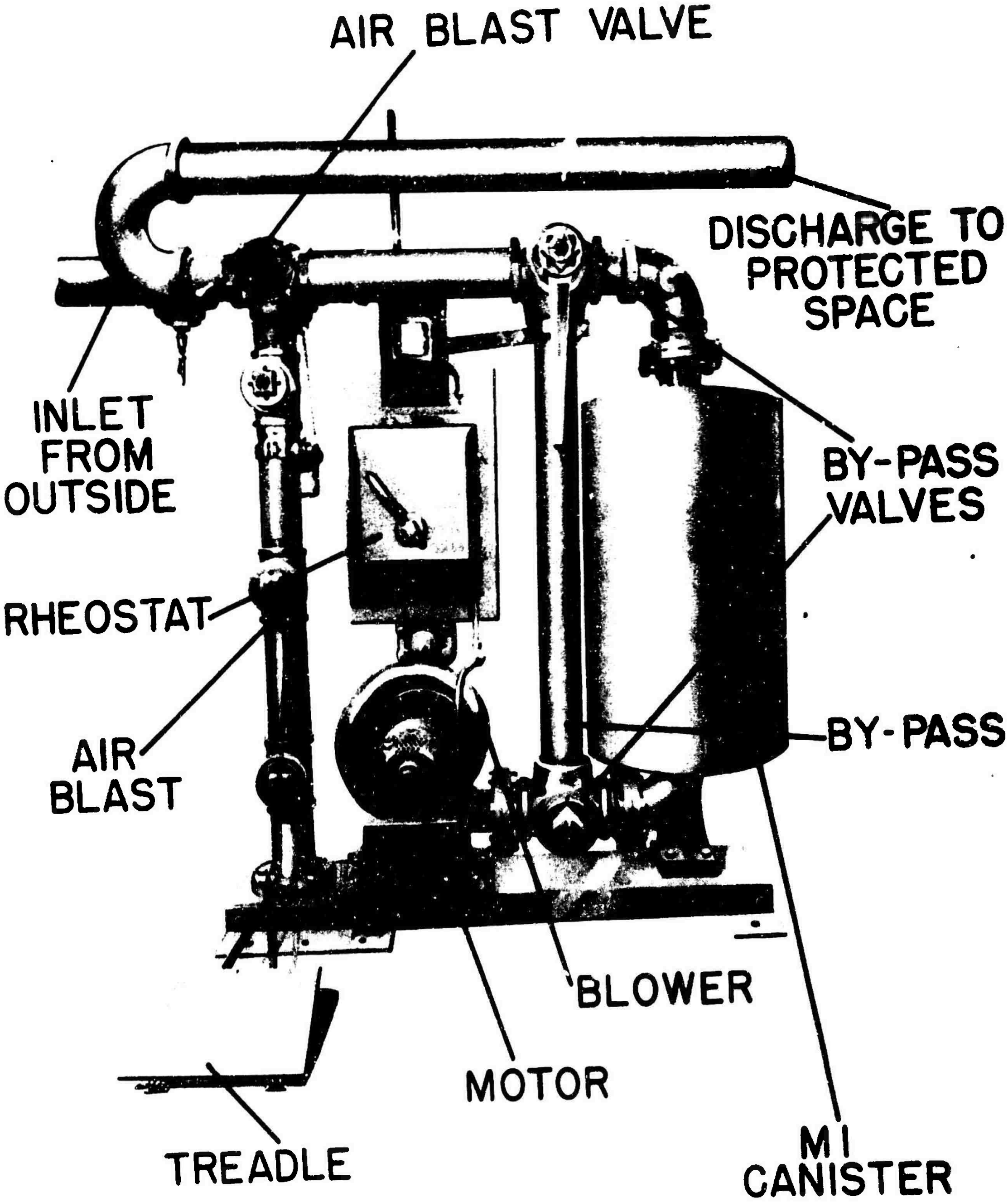


Figure 12. M1 Collective Protector

Figure 13. Collective Protector E1R22 Canister E2

(1) Canister body containing 16 protective units; (2) canister top set in position; (3) flanges for bolts not in place; (4) standard pipe flange; (5) blind flange for temporary seal, and (6) canister, 19 X 19 X 37 in. overall.

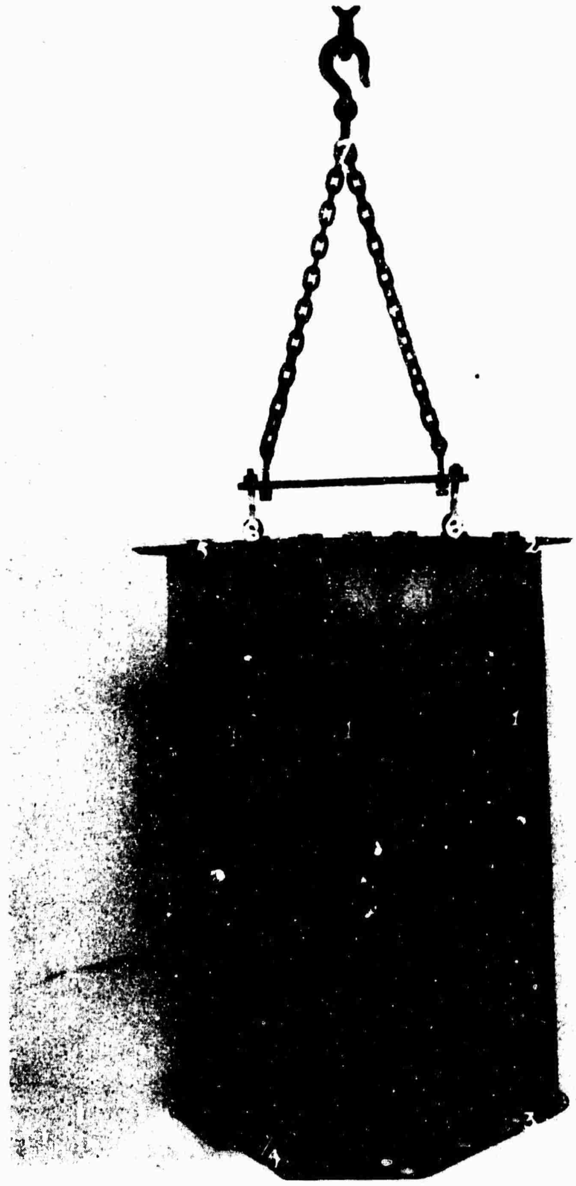


Figure 14. Collective Protector E1R22 Sixteen–Unit Subassembly E2

(1) Alpha web wrapped protective suits; (2) manifold; (3) spacer; (4) ports for passage of unpurified air from below; (5) inner tube extensions for passage of purified air upward; (6) eye-bolts attached to manifold and spacer; and (7) handling sling.

E9R2 and the E10R1 Collective Protectors, whose essential difference lay in the fact that the former was electric-motor driven and the latter was driven by a gas engine. Figure 15 shows the E10R1 Collective Protector. The weight of this large Field Collective Protector was 610 to 620 lb. It could supply 200 cu ft of air per minute against a back pressure of 0.2 in. of water.[17]

The large Field Collective Protectors, described above, could not be used for providing protection in a narrow trench and were too large for small vehicles. A small Field Collective Protector was therefore developed. The result of this development was the E8R6 Collective Protector. Its canister was the same as the M1 but had four instead of 16 tubes mounted in it. It had provision for hand-drive, weighed 225 lb, could provide 50 cu ft of air per minute against a back pressure of 0.85 in. of water, and was gas-engine driven (figure 16).[18]

Field Collective Protectors E8R6 and E10R1 were tested by the Chemical Warfare Board. They recommended that, after minor defects had been corrected, steps be taken to standardize the units.[19]

The large Field Collective Protector M1 was standardized 12 March 1940 and was redesignated the M2 Collective Protector (figure 17) on 2 June 1942. The Field Collective Protector, redesignated M2A1 Collective Protector on 4 August 1942, was an electric motor-driven variation of the M2 Collective Protector.[20-22]

The small Field Collective Protector was standardized as the M3 Collective Protector (figure 18) on 4 August 1942, and military characteristics were approved for the equipment at the same time.[28]

II. MILITARY CHARACTERISTICS.

A. General.

Military characteristics were approved for the large field collective protector, small field collective protector, collective protector for trailer installation, and two types of tank protectors,[23-28] but none were approved for the fortification protector.

There were a number of characteristics that all of the protectors had in common. For ease of discussion, these common characteristics are considered in relation to each of the collective protectors.

1. Air Capacity.

Collective protection is based on the theory of excluding contaminated air from an enclosed space. This is accomplished most practically by maintaining an excess pressure of purified air in that space. The question was resolved by maintaining an excess pressure in the enclosure despite air leakage or by decreasing the air leakage so that the available air supply could build up an excess pressure. In actual practice, a combination of the two methods was used.

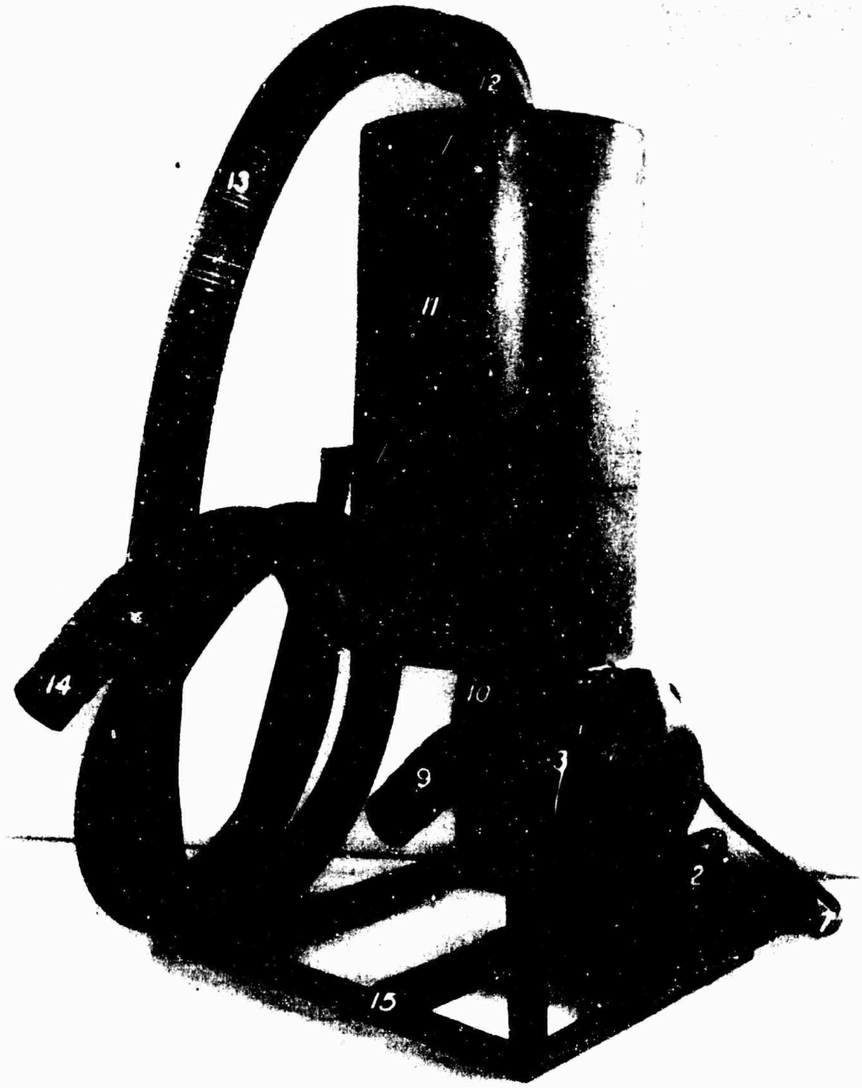


Figure 15. Collective Protector E10R1

(1) Gasoline engine (0.5 - 0.75 hp) for driving blower (8); (2) fuel tank (1 qt); (3) foot pedal for starting gasoline engine; (4) choke lever; (7) flexible exhaust tubing (10 ft); (9) screened intake to blower (8); (10) blower outlet; (11) canister for filtering contaminated air; (12) canister elbow; (13) flexible metallic air hose (20 ft) for conducting purified air from canister into the space to be protected; (14) screen to prevent the entrance of insects and rodents into the air hose; and (15) base and supporting frame of the assembly.

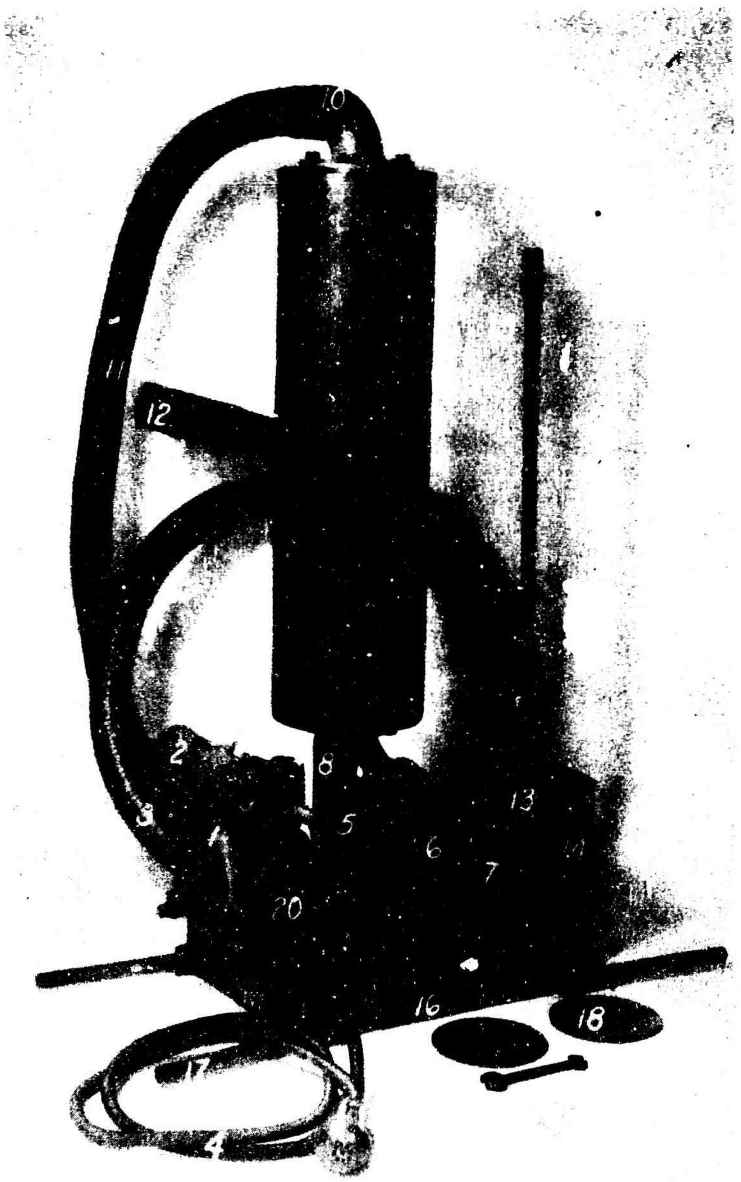


Figure 16. Collective Protector E8R6

(1) Gasoline engine; (2) fuel tank; (3) foot pedal; (4) flexible exhaust tubing; (5) engine driving clutch; (6) blower; (7) screened blower inlet; (8) blower outlet; (9) canister; (10) canister elbow; (11) flexible metallic air hose; (12) screen; (13) clutch; (14) hand drive; (15) hand lever; (16) base; (17) carrying handles; (18) blind flanges; (19) wrench; and (20) lubricating oil filling plug.

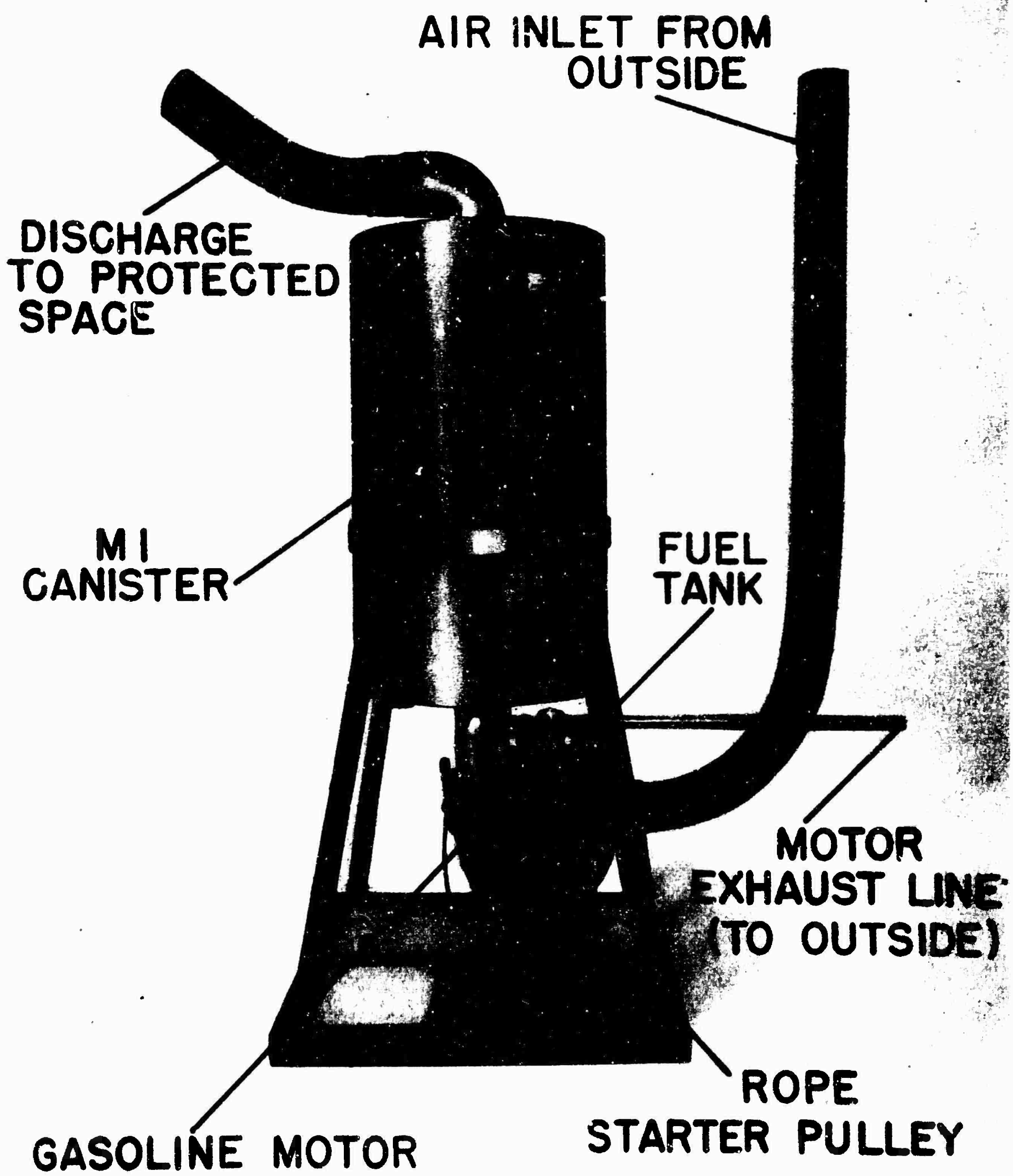


Figure 17. M2 Collective Protector

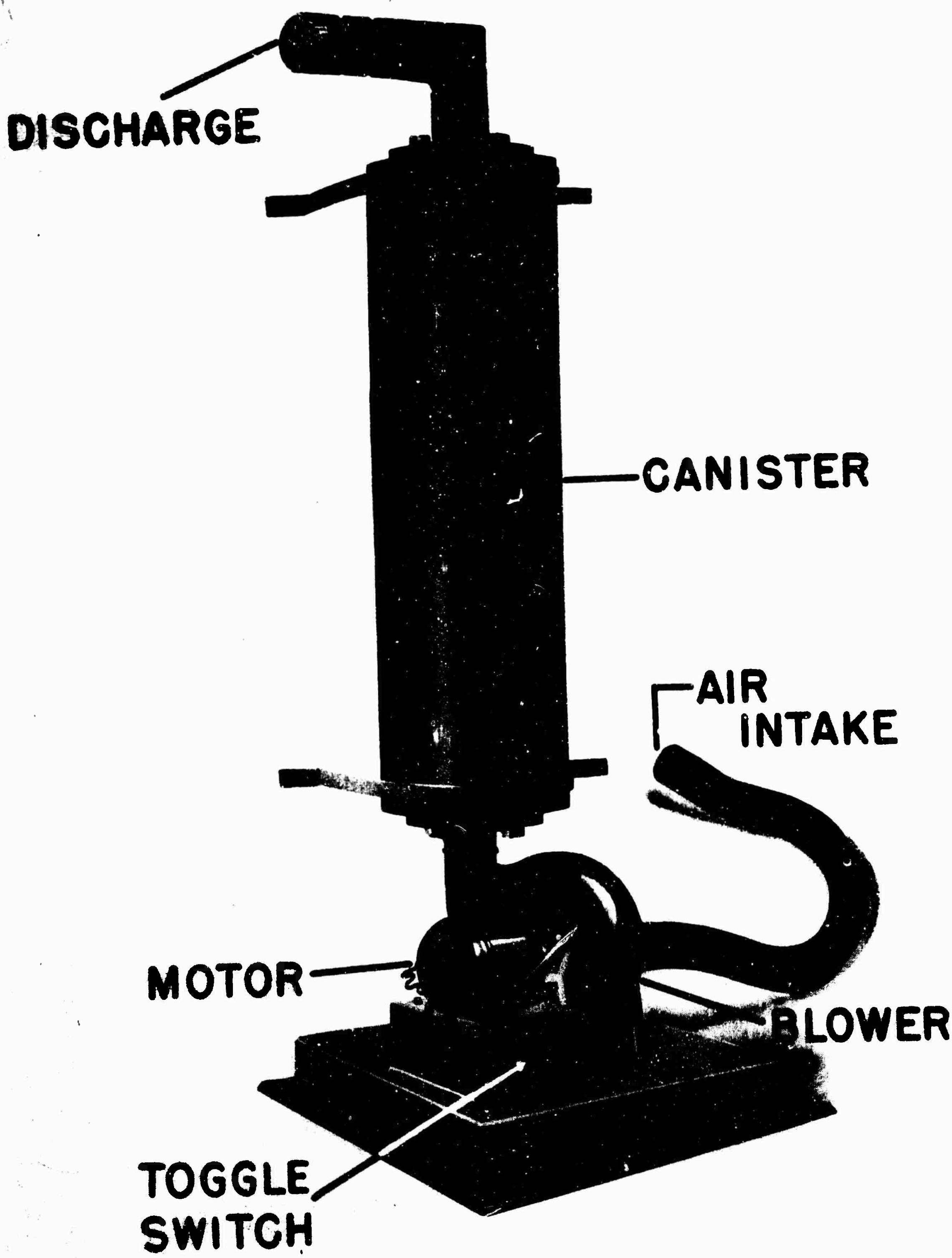


Figure 18. M3 Collective Protector

The air capacity of collective protectors designed for fortifications was 200 cu ft of air per minute. This amount was sufficient for excluding tear gas from a protected plotting room of a gun battery in a test conducted at such an installation. The Coast Artillery Board expressed its approval of the general design of the collective protector.[12] For installations requiring greater air capacities, a number of protectors connected in parallel could be used.*

The requirement of 200 cu ft of air per minute was carried over to the large field collective protector.[24,26] This amount of air was later found to be insufficient and the requirement was raised to 300 cu ft per minute.**

For the small field collective protector, 50 cu ft of air per minute was determined to be enough to protect a dugout of the desired size.[19] A small field collective protector, delivering 50 cu ft of air per minute, also gave good protection in a truck.[29] This specification was adopted as one of the approved military characteristics for the small field collective protector.[19]

Fifty cubic feet of air per minute was adopted as adequate for the collective protector for trailer installations, probably on the basis of tests[23] conducted on a pilot model of flash and sound ranging trailer W337; however, subsequent[29] experience led the writers of a project specification to the conclusion that 50 cu ft of air per minute was insufficient to protect most existing vehicles. The amount they thought necessary was 275 to 300 cu ft of air per minute.**

Two different requirements were set up for protection of tank crewmen. One covered existing tanks. Since the tanks were not airtight, and since air for the engine was drawn through the crew compartment, it was necessary to provide for a filter unit to force air through a hose to a loose-fitting facepiece worn by each man of a tank crew. For this purpose, 4 cu ft of air per minute per man was deemed to be adequate.[25,27,28] This figure was raised to 5 cu ft of air due to results of later tests. The Canadians showed that slightly more than 5 cu ft[30] of air per minute was required for complete protection by this method because of the loose fit of the facepiece. From the standpoint of comfort,† it was believed that anything over 3.5 cu ft of hot air per minute produced a very disconcerting airblast on the face.§ (This situation occurs in closed tanks exposed to the sun in the summer.)

The second requirement was for a tank protector to provide a sufficient quantity of air to maintain a higher air pressure in a sealed crew compartment than exists outside. The Medical Research Laboratory, Fort Knox, sealed an M4A3 tank such that a 1/2-in. static pressure was maintained in the tank with an input of 170 cu ft of air per minute; however, in

*Design of Collective Protector Installation. Army Service Forces, Office, Chief of Engineers. Engineering Manual, Chapter XXV.

**Chemical Warfare Service Project Specification (hereinafter) Project D4.1-12. Field Collective Protector for use in Trailer. December 1944.

†Trials of Chemical Attack Against Protected M4A4 Tank. Air Filtration Unit Military Intelligence Division (Canada). (hereinafter CW Laboratories, Intelligence Section Report No 5.) Oct 1943.

§Determination of the Optiman Method for Protection of Tank Crews Against Chemical Warfare Agents. Armored Medical Research Laboratory (Fort Knox, Ky.) (hereinafter. AMRL) (In TL as ETF 260.1-14) Final Report on Project No. 35. 13 Sept 1944.

order to protect the crewmen in this manner,* it was necessary to cease drawing the engine air from the crew compartment. The amount of air required was 1500 to 1800 cu ft/min for the M4A3 tank engine and up to 2500 cu ft/min for other types.**The loss of these amounts of air from the crew compartment would create intolerable conditions for crew members in hot weather if an adequate quantity of air for cooling purposes was not introduced by the collective protector system. An adequate amount of air was estimated to be 400 to 600 cu ft/min. Since the amount of air needed to assure habitable conditions in the crew compartment was not known precisely, the approved military characteristics were necessarily vague and specified merely that enough air must be provided to maintain a positive pressure in the crew compartment and, also, to place no undue heat burden on the crew when operating in a hot, humid climate.[25,27,28]

2. Size.

Size, as a factor in collective protector design, varied in importance with the particular type of protector under consideration, although all approved military specifications contained some reference that the protector be as small as practicable or small enough to go into some particular space.

For the fortification protector, size was not of prime importance; however, it did have to be capable of installation in an out-of-the-way place where it would not interfere with operation of the fortification equipment.

Size specifications were established for the small field collective protector in the course of its development. One specified, that the "dimensions facilitate installation in a narrow trench." This was restated[19] in the approved military specifications of 25 March 1935.

The approved military specifications for the collective protector for trailer installation called for a size capable of installation and operation in mobile machine shops, laboratories, office trailers, etc.[23]

For the large field collective protector, all the specifications on size merely said in effect that it be as small as practicable;[25,27,28] size in this case was more important than any of the others. Tanks were so filled with equipment that the introduction of any new device necessitated discarding something, such as ammunition.[31]

3. Weight.

Weight varied in importance with the type of collective protector. For fortifications, where all sorts of handling machinery would be available, weight was not significant. In tanks and trucks, weight would have only minor significance and was not discussed in the approved military specifications.[25,27,28] However, when a protector had to be designed for troop use in the field, weight could be of decisive importance. The military specifications for the large field collective protector, therefore, stated that the total weight should be under 400 lb.[24,26]

*Report of Trip to Tank-Automotive Center, Ordnance Department, Detroit, Michigan. 28 Jun 1943.
**Report of Trip to Edgewood Arsenal, Princeton University, Allen B. Du Mont Laboratories, Inc. 29-31 Dec 1943.

4. Ruggedness.

The collective protectors, as all equipment, had to retain their ability to operate effectively after normal rough handling. For example, a truck protector had to be capable of traveling over rough terrain with no impairment of its function.[23]

5. Protection.

The degree of protection to be afforded by the field collective protectors was specified to be equal to that of the standard service canister.[23,24,26]

The specifications for the tank protector required that they shall protect against crash concentrations of nonpersistent agents. Although vaguely stated, the meaning was fairly clear; it meant a higher immediate protection to high field concentrations than could be expected from the standard service gas-mask canisters.[25,27,28] The reason for this was the fear of very high field concentrations that could be built up temporarily in enclosed spaces by the nonpersistent agents; e.g., the breaking of a frangible grenade in the air intake to a tank.

6. Drive.

The three drives used for operating a collective protector's blower were hand, electric motor, and gasoline engine. They were specified alone or in pairs as circumstances warranted. The original drive for the small field collective protector was the gasoline engine with provision for hand operation.[18] One set of approved military specifications also added provision for electric-motor drive as special equipment.[19]

The large field collective protector was to be provided with either a gasoline-engine or an electric-motor drive;* however, the approved military specifications mentioned merely gasoline-engine drive.[24,26] Several years earlier, approved military characteristics for this protector specified electric motor or gasoline engine. It is interesting to note that this set of military characteristics specifically mentioned that hand drive need not be provided.[19]

The collective protector for trailer installation had to be driven by a small electric motor; presumably the electric power was to come from the trailer's batteries or a motor-generator set.[23]

The tank protector for existing vehicles was to be driven by either a 24-v dc motor or a 12-v universal motor, issued as alternate components. The protector for tanks with a sealed crew compartment was to be driven by a 24-v universal motor. In addition, provision was made so that the development of protective equipment for tanks could be coordinated with tank design. Thus, any changes in a tank's electrical system could be quickly translated into changed power requirements for the tank protectors.[25,27,28]

7. Tubing.

It was felt necessary to include in the military characteristics the specification of various lengths of flexible tubing for attachment to the collective protectors. Thus, the

*Project D4.1-12 Specification, op cit.

military characteristics for the collective protector for trailer installation, the large field collective protector, and the small field collective protector specified the need for flexible tubing.[19,23,24,26]

B. Military Characteristics for Specific Protectors.

Many approved military characteristics included requirements that for one reason or another were supposed to help the protector fulfill its particular mission. These were not common to all the protectors and are listed below under the subheadings of the various protectors.[24-28]

1. Large Field Collective Protector.

a. It should be designed so that inexperienced personnel will be able to place the unit in operation in a minimum length of time by following simple instructions.

b. The unit and the component part should be so designed that it can be handled by men without the aid of a crane lift of any kind.

c. The unit should be capable of being broken down into the smallest packages practicable to facilitate handling and shipping.

d. Provision should be made for installation both interior and exterior to the protected space.

e. It should be designed so that the relative invulnerability of component parts of the assembly is approximately the same.

f. The canister should have a positive seal with "not to be opened until presence of gas" stamped on it.

2. Protector for Existing Combat Vehicles.

a. It should be primarily designed for installation in combat vehicles.

b. It should be designed so as to cause minimum interference with the functioning of the combat vehicle crew during normal operation or during firing of weapons.

c. It should be designed to connect to a source of outside air.

d. Provision should be made for delivering all purified air through flexible tubing to loose-fitting, light-weight, full-vision facepieces worn by individual crew members.

e. A dust filter should be provided which has a minimum life equivalent to that of the combat vehicle engine air cleaner.

f. The canister and dust filter should be designed so that they can be quickly and easily replaced.

g. The protector should be sufficiently simple in design so that it can be readily installed by the 4th echelon maintenance personnel.

3. Protector for Tanks with Sealed Crew Compartments.

a. It should be designed so as to cause minimum interference with the functioning of the tank crew during normal operation or during firing of weapons.

b. It should be designed to connect to an outside source of air.

c. The protector should be designed so that all air entering the crew compartment passes through the protector canister.

d. The canister should be provided with a replacement-type dust filter that will remove the dust from the air supplied to the crew compartment.

e. The protector should be designed so that it can be installed in the tank at the plant and at the time of manufacture.

f. Design of protective equipment must be coordinated with tank design to insure proper fit and operation. Of particular importance are: storage space, power requirements, and in the case of the positive pressure system, degree of crew compartment sealing in relation to airflow capacity.

III. THEORETICAL.

A. Collective Protection Concept.

"Measures of protection against chemical agents which apply generally to a group of persons, as distinguished from those measures which pertain solely to an individual, are classed under the heading of Collective Protection, and comprise the following:

1. Provision and use of gasproof shelters where personnel may work, sleep, rest, and eat their meals in a gas-free atmosphere during gas attacks.

2. Removal of gas from enclosed spaces.

3. Decontamination of ground, buildings, clothing, and equipment.

4. Protection of weapons and ammunition.

5. Precautions with reference to food and water.

6. Provision of a protective organization to supply and issue protective equipment, to give warning of gas attacks, and to supervise training of personnel and the conduct of protective measures."[32]

Gasproof shelters were only one aspect of collective protection and two types of such shelters were noted, nonventilated and ventilated. The nonventilated shelter had many shortcomings and actual dangers. They required much greater space per occupant because of the carbon dioxide and moisture discharged into the air by human occupants. Their protection relied on their airtightness, which was an unsafe assumption. During the first world war, many shelters of this type proved to be gas traps.[33]

Ventilated shelters could protect many more men in a more restricted space than was possible with the former type,[33] and they did not have to rely on absolute gastightness since positive air pressures maintained with purified air cause all leakage of air to be outward. Collective protectors supplied air to these shelters.[8]

Collective protectors were filtration devices for supplying air that was free of irritant chemicals to a gasproof shelter in the same manner that a gas mask supplied purified air to an individual.[33] Thus, just as the gas mask was the basic item of equipment for individual protection, the gasproof shelter, provided with a collective protector, was the basic requirement for the protection of groups against toxic agents.[34]

B. Purified Air Requirements.

1. General.

Two fundamental principles had to govern the specification of an air requirement for a gasproof shelter. These were:

a. Air leakage of the shelter.

b. Human physiology; i.e., the air supply in the shelter had to be suitable to sustain life.

2. Air Leakage of a Shelter.

A number of different factors influenced the leakage of air in a shelter. They had more or less effect depending on whether the shelter was above or below ground and on the height of the shelter. Some of the factors that exert an influence are:

a. Wind pressure.

b. Seepage through walls.

c. Window and door leakage.

Good engineering estimates have been made by accepted procedures of the air leakage due to these factors. Various methods could be employed to reduce the magnitude of these quantities.

A rough estimate of air leakage has been made in engineering practice by specifying the probable number of air changes produced by leakage per hour. Such estimates were made

on the basis of previous experience and ranged from one-half to three air changes per hour.[35] For well-sealed shelters, one air change per hour was considered a good figure.[36]

There is a special case of air leakage introduced by the facepiece protector (for tank crewmen and hospital patients) developed originally by the Canadians.* The loose-fitting facepiece used by a man was supplied with air from a small collective protector canister. Sufficient air must be supplied so that a man breathing will not inhale more than the air supplied and thus draw contaminated air into the facepiece. This amount was determined by the Canadians to be a little over 5 cu ft of air per minute.

3. Physiological Requirements.

a. Carbon Dioxide Content in Air.

Normal air contains 20.94% oxygen and 0.03% carbon dioxide by volume. The controlling factor in the respiratory process is the amount of carbon dioxide in the inhaled air. This is much more important than the depletion of oxygen. The oxygen content of inhaled air could fall to 14% without harmful effect. Air containing as little as 10% oxygen will support normal breathing, although the breathing rate will be increased. As little as 3% carbon dioxide in air causes a noticeable increase in breathing rate accompanied by headache and increased blood pressure; 4% will impair respiration; and 5% or more is very dangerous. Thus for safety, the carbon dioxide content in air for respiration should not exceed 2%.[33]

b. Relative Humidity.

The relative humidity exerts a large effect on the ability of the body to regulate its temperature particularly at high ambient air temperatures. The effective temperature may be translated into wet and dry bulb readings by means of a nomograph.[35] Table I shows the upper limit of relative humidity for borderline comfort and the limit above which heat prostration may result.

Table I. Relative Humidity for Borderline Comfort and Heat Prostration

Temperature °F	Borderline Comfort RH	Heat Prostration RH
50	85	–
60	80	–
70	70	–
80	60	92
90	45	90
100	40	75

*CW Laboratories, Intelligence Section Report No. 5.

The body liberates 0.15 lb of water per hour in exhaled breath and several times this amount when sweating.[33] These facts correlated with the data shown indicated the importance of reducing the moisture accumulation in shelters.

c. Human Heat Load.

A man at rest generates abc. ' 400 Btu/hr, which is enough heat to raise 600 cu ft of air about 30°F. As high as 1310 Btu/hr may be generated by men working. Thus, in a well insulated shelter with very low heat conductivity through walls, doors, and windows, the amount of air needed for removal of this generated heat might well be the determining factor in the design of ventilating equipment.[33,35]

d. Other Heat Loads.

Sensible heat may be added to the atmosphere by heating units or by gasoline motors as in tanks.[11] This heat must be considered in addition to the human heat in calculation of the total heat load in a gasproof shelter.

e. Effect of Air in Motion.

Increasing the movement of the air in a room decreases the effective temperature of air of the same wet and dry bulb. In hot, humid conditions where the effective temperature is below 100°F, placing auxiliary fans in operation in a protected shelter will increase the comfort of the occupants.

f. Conditions for Optimum Comfort.

The ranges of both wet and dry bulb temperatures for optimum comfort were quite small and could not be obtained without elaborate, year-round, air-conditioning equipment. In gasproof shelters, such optimum conditions could not be obtained because of the prohibitive costs and equipment needed.

4. Tests to Determine Air Requirements.

A series of tests were made to determine the smallest quantity of air required by a man remaining for 8 hr in a plotting room of a fort. For 8-hr periods, 1, 3, and 5 cu ft/min of air per man were supplied to 15 men. The dry bulb temperature varied from 79° to 87°F and the relative humidity from 79% to 92%. A physiological effect was noticeable only when 3 and 1 cu ft/min of air were supplied. This manifested itself as a very slight body temperature rise; however, there were no ill effects. At no time did the carbon dioxide content of the air go above 1.2%.

The recommendation was made that 1 cu ft/min of air per man be considered the absolute minimum supplied, and where mental and physical efficiency are required, 5 cu ft/min be supplied; however, where conditions were more unfavorable (the walls are

poorer heat conductors or the dry and wet bulb temperature higher), considerably more air could be required.

The main shortcoming in the series of tests was that at no time did the air supplied maintain a positive pressure in the plotting room. This introduced the probability of air leakage and thus rendered the amount of air supplied per man subject to doubt.[37]

A number of tests were conducted with field collective protectors to determine the minimum air supply needed to prevent the development of adverse physiological symptoms. The tests were run with dry bulb temperatures of 70° to 80°F and relative humidities of 75% to 90%. Men showed no effects after spending 1-1/2 to 2 hr in a shelter supplied with as little as 1 cu ft/min of air per man.[38]

5. Air Supply for Ventilated Shelters.

Table II specifies the amount of air to be supplied per man in a ventilated shelter under different conditions of temperature and activity.[33]

Table II. Air Requirements per Man in Ventilated Shelters

Temperature of outside air °F	Men performing normal duties: Underground shelters or above-ground shelters with walls of low-heat conductivity* (cu ft/min)	Men performing normal duties: Above-ground shelter with walls of high heat conductivity** (cu ft/min)	Men completely at rest in rest shelters (cu ft/min)
Above 90	4 to 5	2 to 4	1.5
Below 90	2 to 4	1.5 to 3	1 to 1.5

*Walls of wood or dry earth have low heat conductivity.
**Walls of metal, concrete, masonry, and damp earth have high heat conductivity.

NOTE: High relative humidity increases the amount of air required per man.

German practice for air requirement was outlined in captured documents. A formula for use in fixed fortifications when guns were not firing was:

$$\text{Duration of air reserve in hours} = \frac{\text{volume of min/cu m}}{\text{No. of occupants}}$$

After this period, the ventilation plant (and, if necessary, the filtration unit) were run for a period of 10 min at intervals depending on air capacity and the number of men in the room.

C. Collective Protector Canister Design.

1. Elements of Adsorbent Bed Design.

a. General.

Until the early 1940's collective protector charcoal beds had to be designed on the basis of past experience with similar beds, or from data obtained from tests of small models having the same bed depths and air velocities through the beds as those of the large collective protector. No prediction as to performance could be made for a change of bed depth, flow rate, or gas concentration. Mathematical treatments, based on chemical engineering principles, have changed this picture and permit the designer to predict performance of a large collective protector charcoal bed (both air resistance and gas life) from a screen analysis of the charcoal and a single series of tests in any type of container using each test agent.[39] These mathematical methods are discussed fully in the theoretical section of the Gas Mask Canister Monograph and are not repeated here. Instead, a qualitative discussion of charcoal-bed design with various examples of actual practice follows:

b. Mechanism of Adsorption.

It was believed that the adsorption of a gas by charcoal consisted of two phases: (1) the diffusion of the gas to the charcoal surface and (2) the reaction between the gas molecule and the charcoal. This reaction could be adsorption or chemical reaction (catalytic oxidation or decomposition).

The gas-air mixture was thought of as moving in the form of a concentration wave. When the gas-air mixture first entered the charcoal bed, its concentration was immediately reduced until by the time it had progressed some distance into the bed, the gas concentration was reduced to zero. As the initial layers of charcoal were saturated, the wave proceeded undiminished until it reached a point where the charcoal was not saturated and could again adsorb the gas. This phenomenon is illustrated graphically in figure 19.

The assumption of the above led to the concept of a two-layer charcoal bed. One layer, the active layer, reacted with the gas to the extent that the charcoal capacity was completely used, while the second layer, the critical layer, served to reduce the concentration to a point that was regarded physiologically significant. This idea is depicted in figure 20.[39]

c. Effect of Charcoal Bed Depth and Air Velocity.

Figure 21 shows a series of plots of bed depth versus the phosgene gas life at a number of different air-gas velocities. At a given charcoal bed depth, increasing the velocity will decrease the gas life. The plots indicated that the bed depth was directly proportional to the gas life at a given airflow. This series of plots also illustrated the critical bed depth, which is the depth of a charcoal layer at zero gas life.[39]

The importance of concept of the critical layer was illustrated by the increase in gas life, which accompanied the increase of the depth of the charcoal layer of the M10 gas mask

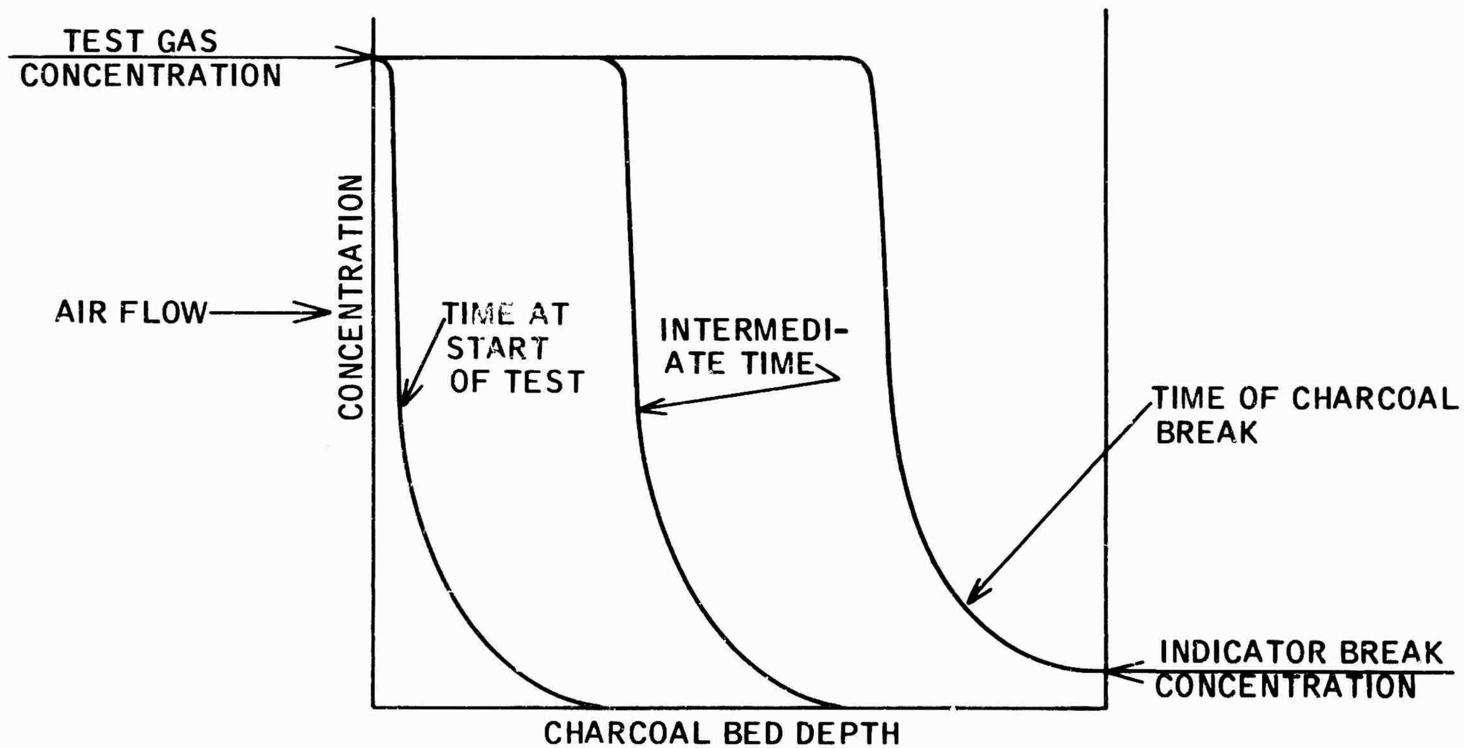


Figure 19. Diagram Illustrating Wave Concept During Charcoal Testing

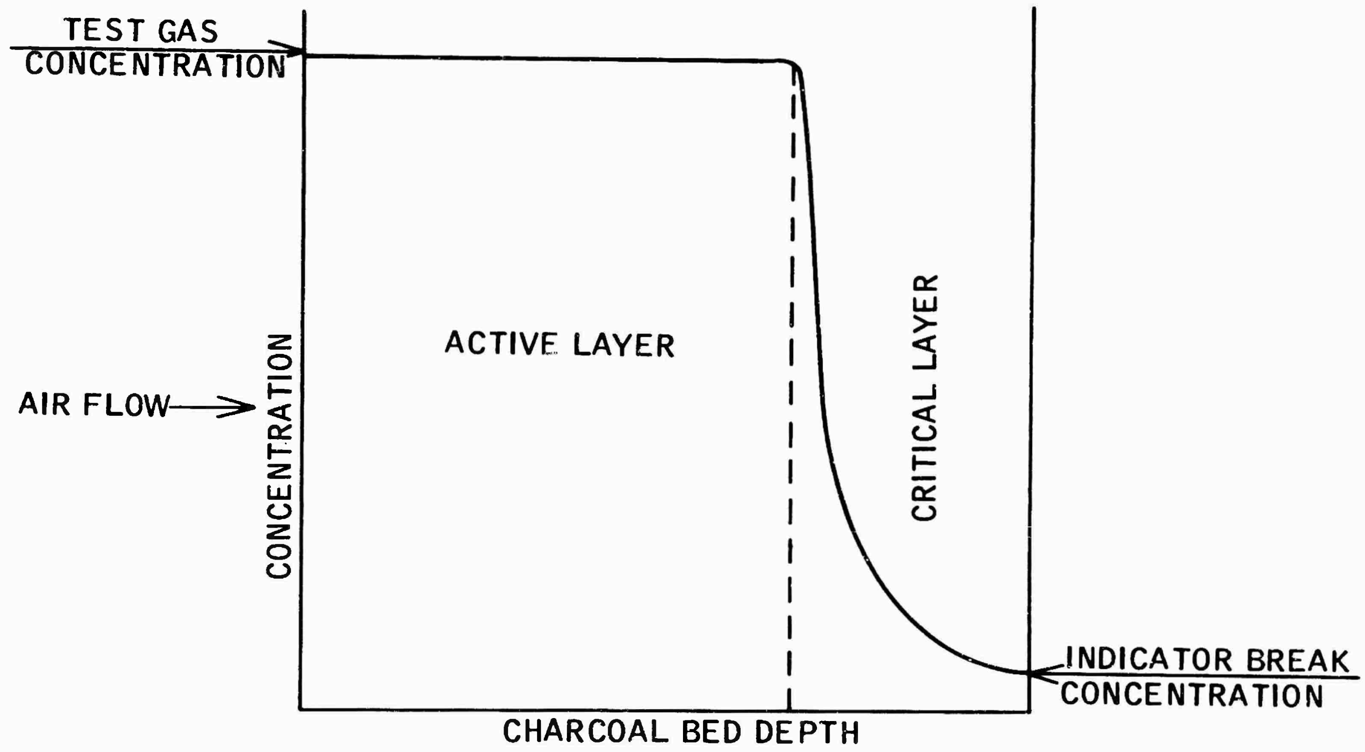


Figure 20. Diagram Illustrating Active and Critical Layers in Charcoal Bed

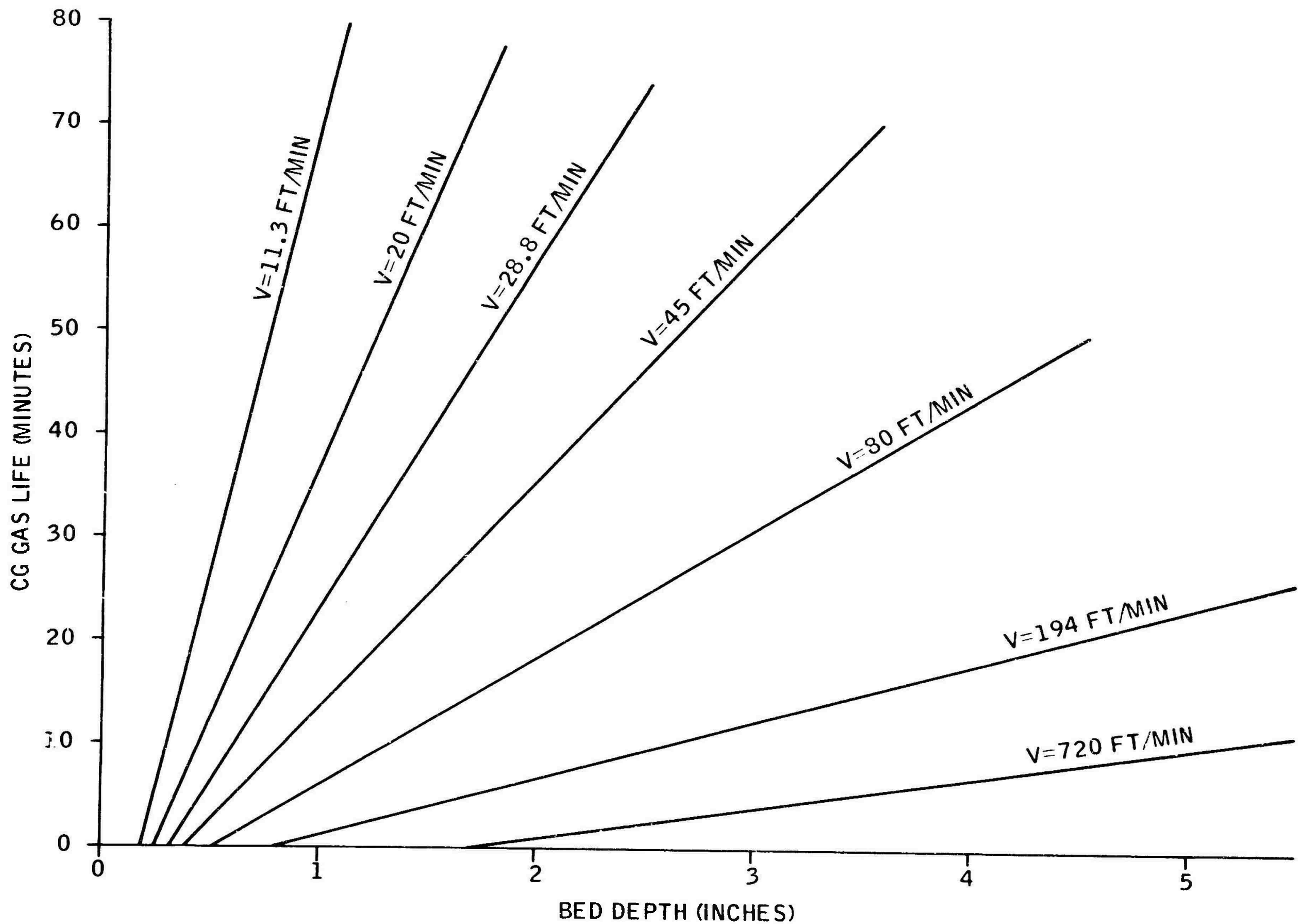


Figure 21. Effect of Air Velocity and Bed Depth on Gas Life

canister by 3/32 in. The gas life under various conditions showed an improvement of from 30% to 200% simply because the original bed depth had been so close to the critical depth under the conditions of use.[40]

d. Air Resistance.

Figure 22 illustrates the effect of charcoal bed depth on air resistance; the air resistance was a linear function of the charcoal bed depth. Figure 23 shows the effect of velocity on the pressure drop of a charcoal bed. The slopes of these curves were approximately 1, showing that air velocity was almost proportional to air resistance at the velocities treated.[39]

Figure 24 shows an interesting relationship between air velocity and air resistance for a constant gas life. These curves indicated that a charcoal bed designed to work at air velocities below 30 ft/min would give better performance (since the pressure drop increases at a much slower rate up to this point), for a given degree of protection, than a bed designed to work above this point.[39]

Air resistance (or pressure drop) was an important consideration in collective protector design, especially when several beds were used in parallel as in the M2 Collective Protector Canister. If one of the charcoal beds were lower in pressure drop than the others, it would tend to take a greater proportion of the airflow, causing its gas life to drop.*,[41] To obviate this possibility, a requirement was added to the specification that the component tubes of the M2 Collective Protector Canister should have resistances within 2 mm of one another.**

At one time, the pressure drop of M2 Collective Protector Canisters being produced was reduced. This caused the airflow delivered to be greater than the specification and could result in premature failure of gas protection. An orifice had to be inserted in the canister to regulate the airflow to prevent this type of failure.[41]

e. Charcoal Mesh Size.

Figure 25 shows the effect of charcoal mesh size on gas life; the smaller the charcoal particle size at a given bed depth the greater the gas protection of the bed. The curve for 30- to 40-mesh size had a lower slope than that for other mesh sizes because of the poorer ability of small charcoal particles to become activated. From figure 23 the relationship between charcoal mesh size and pressure drop could be deduced. The smaller the particle size of the charcoal the greater the resistance to airflow at a given velocity.[39]

f. Radial- and Axial-Flow Beds.

Charcoal beds were divided into two main classes, radial flow and axial flow. The radial-flow-beds were essentially cylindrical and the air flowed through the beds radially from the outside to the center. Beds of the axial-flow type were essentially flat and air flowed through perpendicular to the bed. American practice, up until the start of the second world war, was to use radial-flow beds exclusively in charcoal-bed design, although no foreign country used anything but axial-flow beds in its collective protectors.

*Project D4.1-12 Specification, op cit.
**CWS Specification 197-54-107A, 22 April 1944.

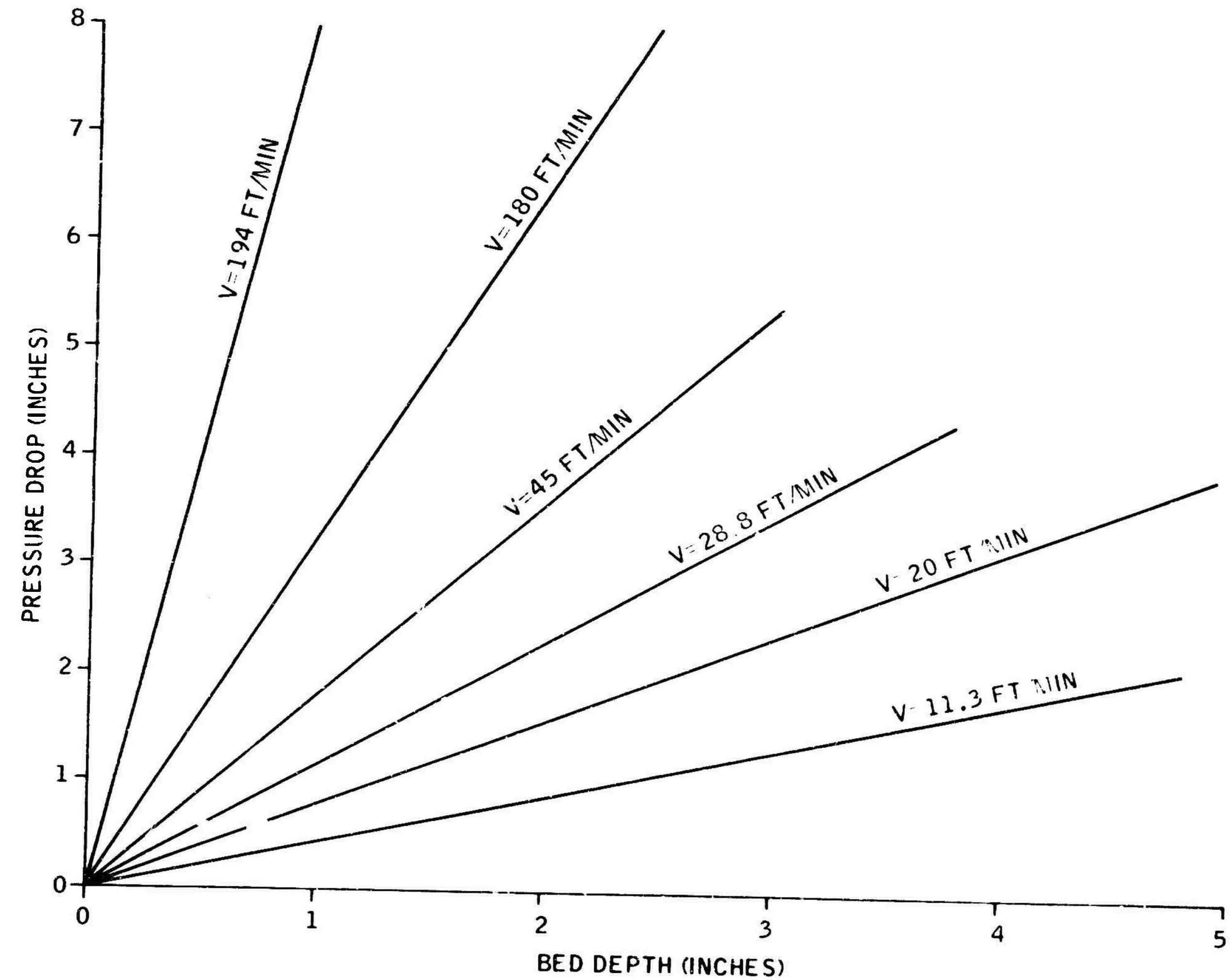


Figure 22. Effect of Bed Depth and Air Velocity on Air Resistance of Charcoal Bed

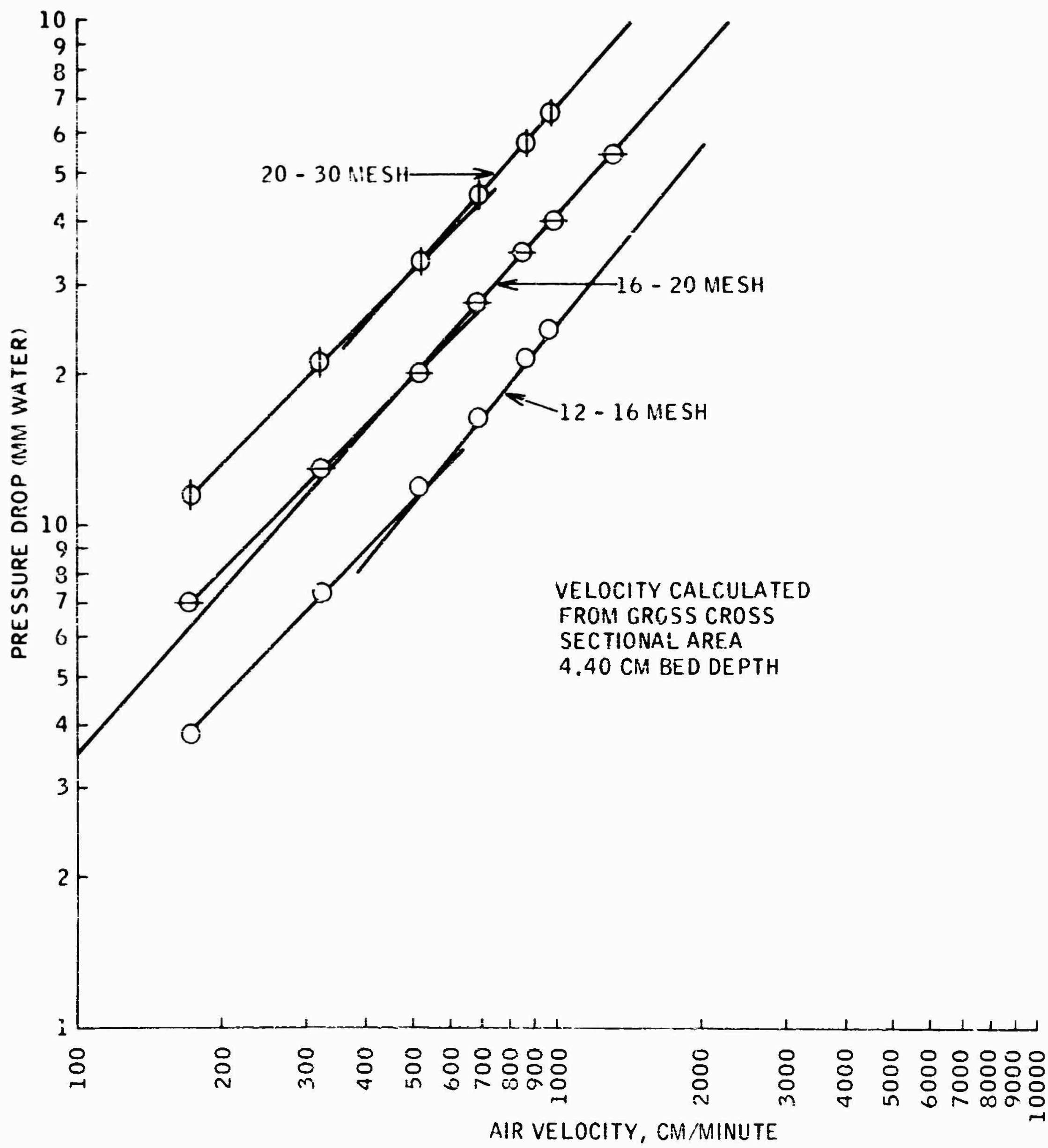


Figure 23. Pressure Drop vs. Flow Rate Charcoal HC3-361 E3 and E2R3 Canisters

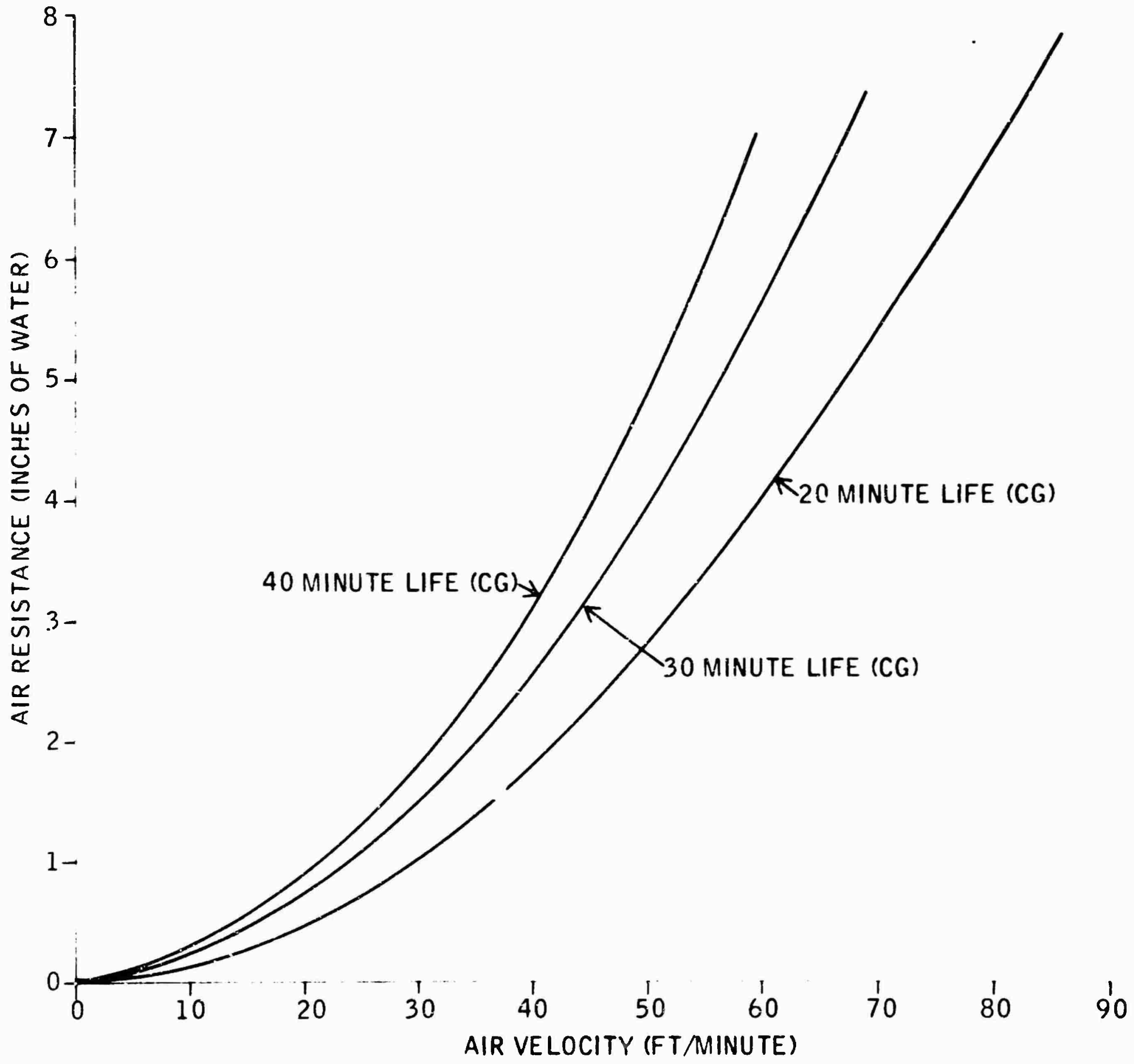


Figure 24. Effect of Air Velocity on Air Resistance at Constant Level of Protection (Gas Life)

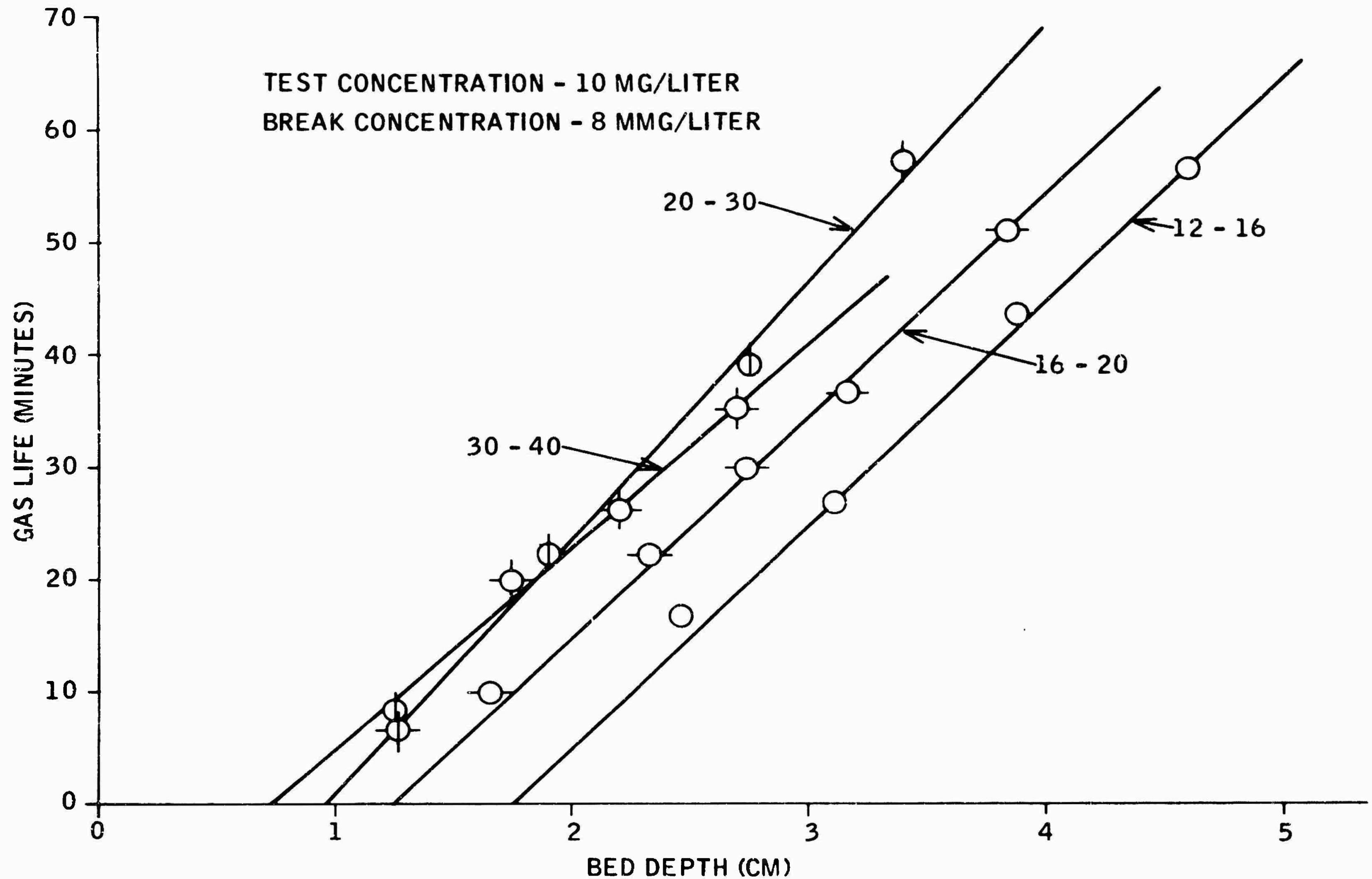


Figure 25. CG Life, Effect of Mesh Size and Bed Depth E3 Canister, 50 L/M Breather Charcoal HC3-361

The basic unit of the American collective protector was the M1 Collective Protector Canister air purifier. The tube is a good example of a radial-type filter design. The charcoal was retained between two concentric cylinders of perforated metal. Sixteen tubes arranged in a large container comprised the M1 Collective Protector Canister, which had a rated airflow of 200 cu ft/min. Four tubes in a smaller container constituted the M3 Collective Protector Canister which had a rated airflow of 50 cu ft/min.

The tube was filled with about 4 liters of charcoal and had a phosgene adsorption life of* at least 15 min before rough handling when tested with 20 mg/l of phosgene and 12.5 cu ft/min flow.**

An example of axial-flow filter design was the MITE9 Collective Protector Canister shown diagramatically in figure 26. The charcoal in this collective protector canister was divided into two beds. Fifty pounds of charcoal was held in the characteristic flat bed design between two perforated plates forming the ends of a shallow box. The canister had a phosgene adsorption life of about 37 min against a gas concentration of 10 mg/l at its rated airflow of 300 cu ft/min.

One advantage of this axial-flow design over the radial flow may be deduced fro :' its size and weight. The MITE9 Collective Protector Canister had a weight of 0 83 lb/cu ft of purified air delivered while the M1 Collective Protector Canister had a weight of 3 lb/cu ft of air delivered.[42]

g. Baffles.

Baffles were incorporated in almost all charcoal beds. They are strips of metal placed along the edge of charcoal beds to prevent the leakage of air between the retaining component of the charcoal bed and the charcoal bed itself. The seal made by charcoal granules to metal was not a perfect one and any loosening of the charcoal caused a void in the bed. In the design of the civilian collective protector, where flat beds were placed on edge, baffles 2-1/2 in. wide were put across the top of the charcoal bed because it was feared that vibration of the charcoal would cause enough settling to result in a void which would allow passage of contaminated air.[43]

Since baffles reduced the open area of a charcoal bed and thereby increased the resistance to airflow, they had to be made as small as was commensurate with safe practice.

h. Rigidity of Bed.

To insure good performance, a charcoal bed had to be held fairly rigid. Any shifting of the bed would cause voids, or thin spots where the depth of the charcoal layer was less than in other spots. This would allow a greater airflow and earlier gas penetration through those spots and a consequent reduced life for the whole canister.[43] The desired rigidity could be achieved much more readily with the annular radial-flow bed than with the flat axial-flow bed. To support the axial-flow bed all sorts of stiffening devices were used. For example, in the

*Directive No. 80, Filling Machine for Collective Protective Chemical Containers.
**CWS Specifications Nos. 197-54-47B and 86.

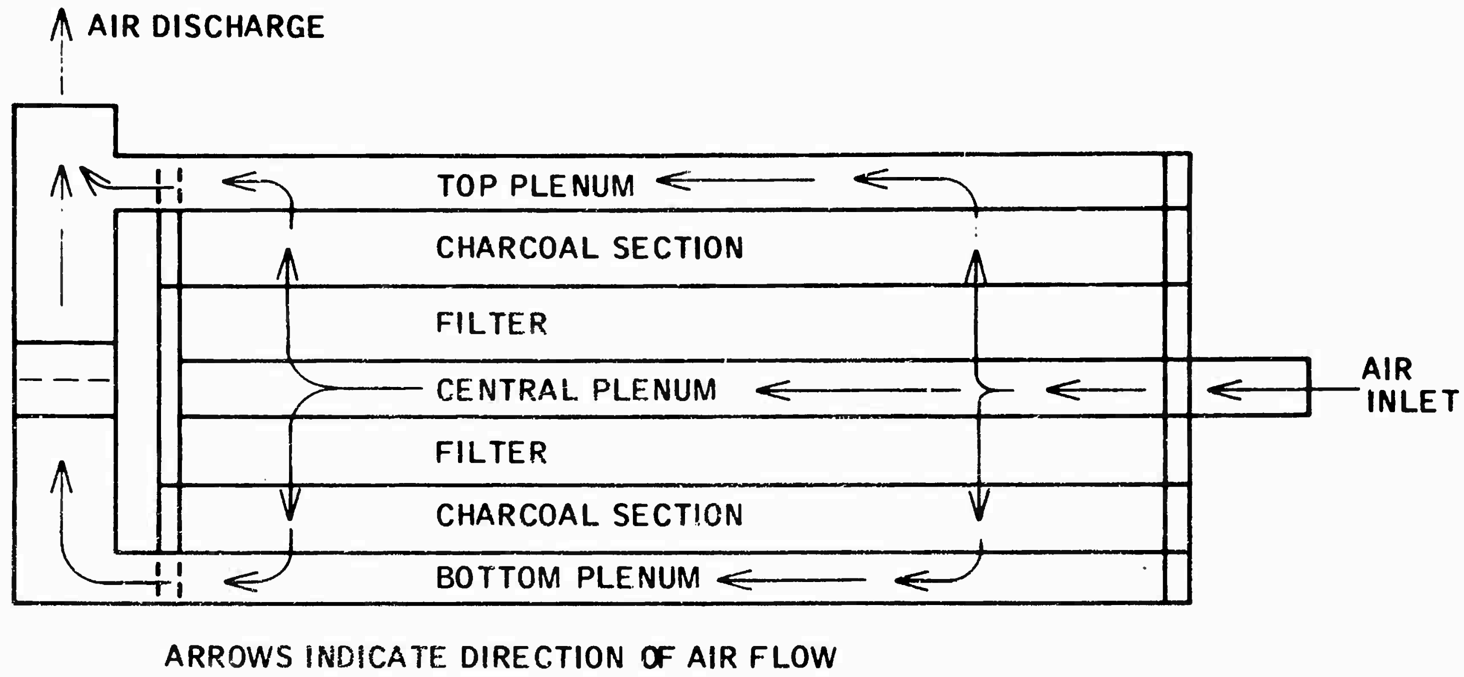


Figure 26. Sketch of Canister of MIT E9 Field Collective Protector

civilian collective protector steel rods, 1/4 in. and 3/8 in., running in both horizontal and vertical directions, were placed across the face of the perforated plate retaining the charcoal.[43] The German 10-cu m/min Collective Protector and the MITE9 Field Collective Protector employed bolts running through the charcoal beds.*,[42] The German 1.2-cu m canister used compression springs bearing on the spacer holding the charcoal bed (figure 27), while the E21R3 Facepiece[44] Protector had expanded metal stiffening the perforated metal spacers.[30]

i. Fines Filter.

In all charcoal beds a small percentage of the charcoal is extremely fine. This fine charcoal could be blown out of a bed causing a great deal of dust. To alleviate this difficulty, fines filters which retain these small particles are incorporated in the design of charcoal beds.

In the M1 Collective Protector Air Purifier, a porous felt bag covered the inner tube and prevented charcoal fines from entering the purified air.** The E21R3 Facepiece Protector Canister had a layer of "Filtocloth" (a cotton mat made by Johnson & Johnson) or glass fiber storage battery plate separating matting plus resin wool for this purpose.[30]

j. Improvement of Adsorbent Layer.

(1) Dehumidification of Charcoal.

Type A charcoal used in collective protection canisters before the advent of Type ASC charcoal, lost its ability to adsorb cyanogen chloride and arsine to any extent when it had become equilibrated to 55% relative humidity or higher. Charcoal became equilibrated to the relative humidity of air being drawn through in a matter of hours. The problem was therefore quite serious since after a short period of operation in a climate having high relative humidities the collective protector would not be effective against some of the war gases. However, it was found that humidified Type A charcoal, when dried, recovered its initial protective abilities. This drying could be accomplished in one of several ways: (1) drawing the air through the canister when the ambient relative humidity falls to 30% or below; (2) drawing the air through a moisture adsorbent included in the collective protector; (3) decreasing the relative humidity of the air by heating it to 180°F and then drawing it through the collective protection canister.[45] Type ASC charcoal was also sensitive to adsorbed moisture in that it deteriorated on being stored wet.

A test was developed to determine the relative humidity of the air to which the charcoal of a collective protection canister had become equilibrated. The test consisted of a small exhauster drawing a few liters of air per minute through a canister and a hygrometer. The air was drawn through at a slow enough rate so that all the humidity could become equilibrated with the charcoal. Figure 28 shows this tester.[46]

*FMTRMIT52, German Collective Protectors 0.6, 2.4, and 10 Cubic Meter per Minute. 31 August 1945.[42]

**CWS Specification No. 197-54-107A. 22 April 1944.

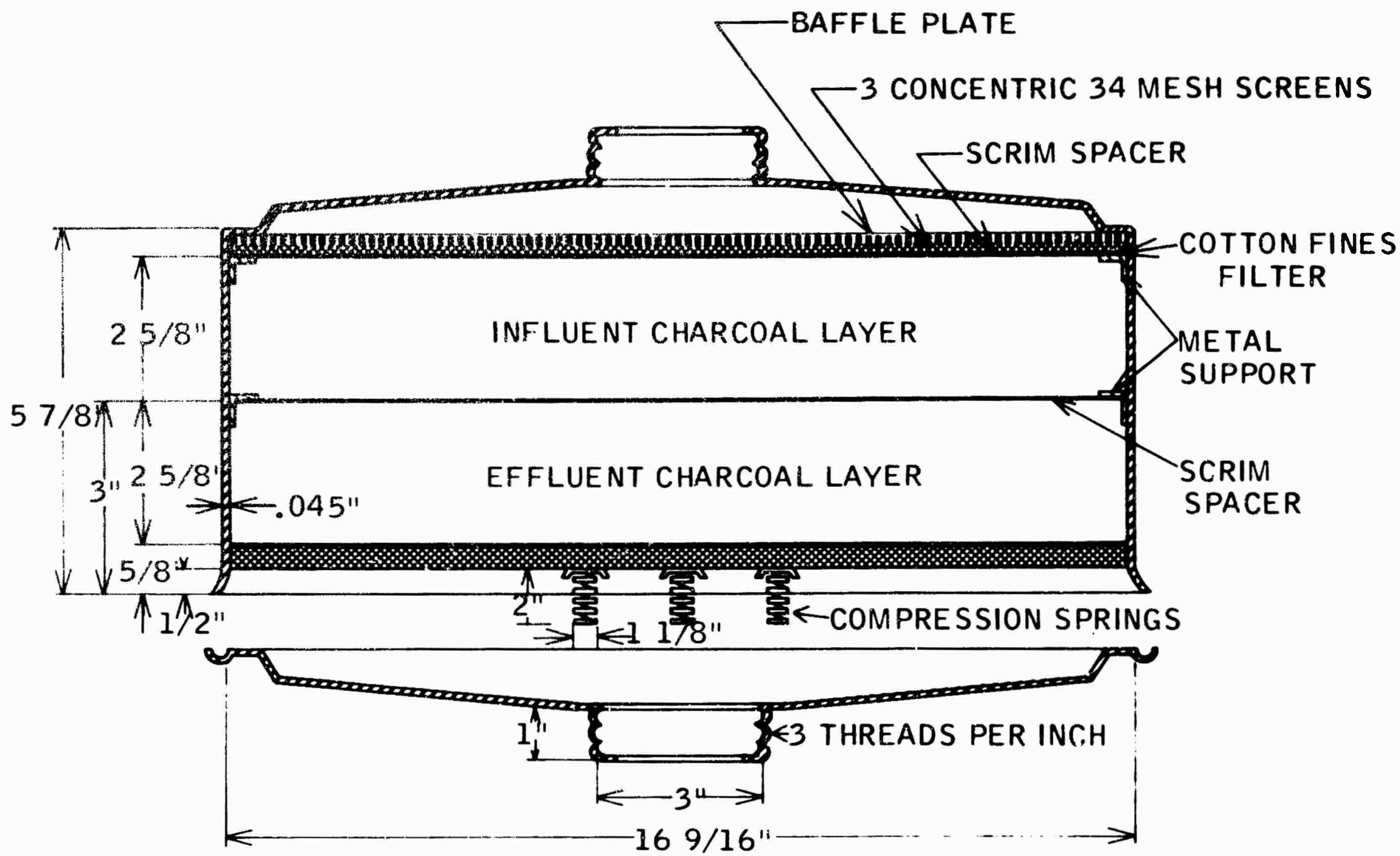


Figure 27. 1938-39 German 1.2 M^3 Collective Protector Charcoal Canister

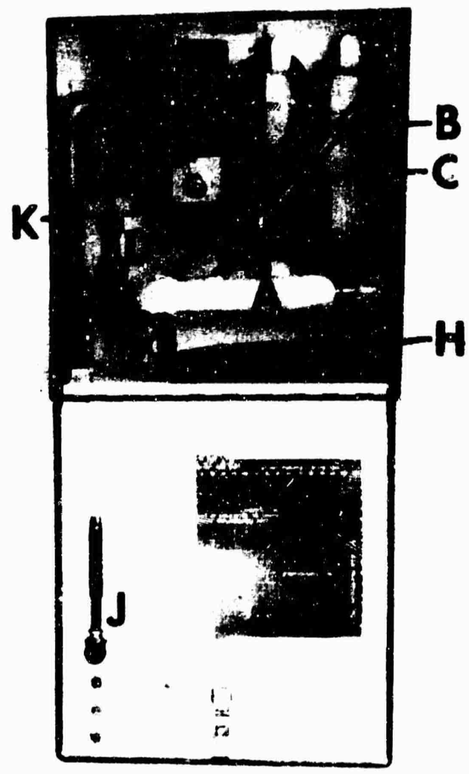


Figure 28. Meter, Humidity Test, E1R5

A. Psychrometer tube; B. dry bulb thermometer; C. wet bulb thermometer; D. gate valve (control air flow); E. ball type rotameter; F. electric blower, to be operated from 6 volt dc or (through transformer, K) from 110 volt ac; G. water bottle for wet bulb thermometer; H. connecting tube; I. serviceability charts; J. pipe fittings to connect psychrometer to canister; and K. transformer for 110 volt ac operation.

Heated air was the method chosen for drying collective protection canisters. This method lent itself most readily to simple and effective use. Figure 29 is a set-up using a gasoline air heater while figure 30 shows a field expedient which employed some iron pipe and the gasoline heater or a M1937 Field Range.

(2) Pyridine Impregnation of Charcoal Bed.

The cyanogen chloride protection of a humidified charcoal bed could also be improved by impregnation of the bed with pyridine. Vaporized pyridine drawn into a Type A charcoal layer improved the cyanogen chloride gas life of humidified charcoal without affecting its ability to afford protection against the other war gases. However, the best pyridine impregnated Type A charcoal gave only one-half to one-fifth the protection against cyanogen chloride under "wet" conditions than was obtained with Grade II, ASC whetlerites. Since recommendation had been made that all collective protection canisters filled with Type A charcoal and Type 1 filter material be considered absolescent and replaced with canisters containing Type ASC charcoal, it was not recommended that any canister in the field be impregnated with pyridine.[47]

2. Smoke Filter Design.

a. General.

The smoke filter of a canister is provided for removal of toxic chemical warfare agent particles which were larger than molecular in size. The charcoal bed removed the molecular constituents of the airborne agents.

Smokes were generally formed by the condensation of vapor in air by rapid cooling. Depending on the conditions, the particle size of such smokes were generally very small, in the order of 0.1 to 1 micron (0.001 mm) in diameter. Smokes were also formed by mechanical disintegration of substances. In general smokes were of any form of particulate matter which existed in a relatively stable dispersion of air. The particle size varied from 0.1 micron[48] for the condensation mentioned above to 20 microns for airborne pollen to even larger sizes.

It was believed that in order to filter a smoke particle from the air it was merely necessary to bring the smoke particle into contact with a fiber of the filtering medium. Thus, the larger the particle the greater the ease of filtration. For smaller particles diffusion or Brownian movement became controlling. Since the rate of diffusion increased with decreasing particle size, the filtration of very small particles also constituted no problem since their probability of hitting a fiber was very great. Particles of 0.2- to 0.3-micron radius, were calculated to be within the range for greatest percentage penetration of fiber-type filters. Military filters were designed to protect against these sizes.[49]

A complete discussion of various other aerosol filtration theories and equations was discussed in the Gas-Mask Canister Monograph. The main conclusions to be drawn from these theories were that the smaller the fiber size in the filtering medium the better the filter, and that the optimum penetrating particle size, discussed above, may be determined by means of fine fiber sizes in filter materials.

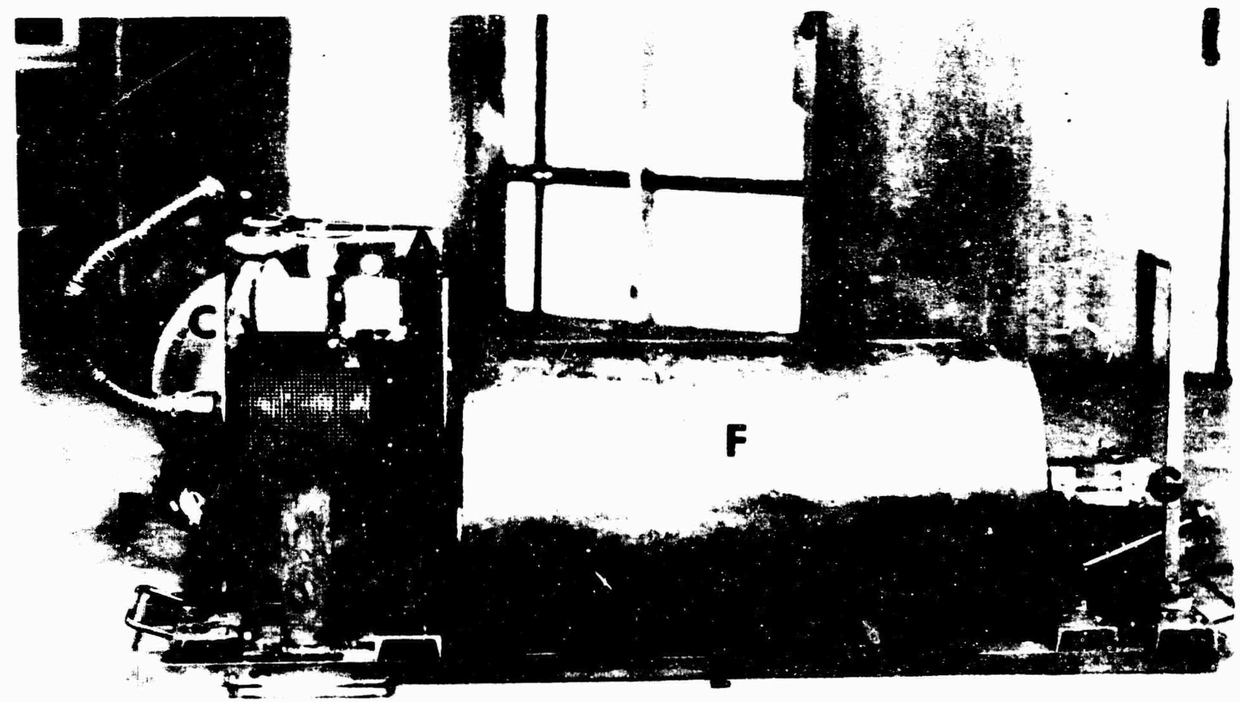


Figure 29. Apparatus, Drying, Canister, E2, with Collective-Protector Canister M1

A. Gasoline heater; B. heater exhaust extension; C. blower; D. generator; E. frame; F. collective-protector canister, M1; and G. quick-acting clamp.

Figure 30. Collective Protector Canister Dryer (Field Model)

A. M1 collective protector canister; B. gasoline heater; C. gasoline engine; D. blower; E. connecting tubes; F. thermometer (for air leaving canister); G. heater control switches; H. needle valve; I. flow control valves; J. supporting frame; and K. sandbags.

b. Filter Materials.

The following materials have been used in collective protectors:

1. Rock wool

2. Wood pulp/asbestos combinations

3. Resin wool

4. Asbestos/wool, or/cotton

5. Paper

Rock wool was a material widely used for heat insulation purposes. It was made by blowing steam jets into a bath of molten glass, collecting the resulting glass fibers and pressing them with a suitable binder to make a pad about 1-in. thick. It had been used to filter city gas for some time. However, it was not used[49] in collective protection canisters till the development of the M4 Collective Protector. The pads used had a pressure drop of about 0.37 to 0.50 in. of water per pad at an air velocity of 28 ft/min. Four pads were combined in series to form a smoke filter of sufficiently low penetration. A wood pulp pad charged with 10 to 15% Canadian Chrysatile asbestos was also tried in the above-mentioned collective protection canister. Four pads of this material were also combined in series.[43]

Resin wool filters were made by mixing a resin with wool fiber and carding the mixture so as to produce an electrostatically-charged pad. The filter material thus produced was very efficient for smoke filtration, possibly better than any other. However, it was not used to any extent in this country because the electrical charge could leak off under some conditions with a resultant loss of most of the filter's efficiency.[50] This filter was used by the Italians in their collective protectors[51] and by the British and Canadians in their gas-mask canisters.

To correct the defects of resin wool filters, an attempt was made to develop an asbestos/wool filter, but the filtering efficiency of such a filter was quite low. However, the Germans in one of their collective protectors used a cotton-asbestos pad-type filter.*,[44]

Felted paper was by far the most widely used filter material in collective protectors and gas-mask canisters in this country. Table III gives a resume of the filtering efficiency (an arbitrary quantity based on the DOP smoke penetration and the air resistance), and composition of the various filter papers used in collective protectors.[52]

c. Effect of Air Velocity on Smoke Penetration.

The effect of changing the air flow rate through filter material was deduced. This figure shows the results of testing three different paper pads at three flow rates and with smoke of various particle sizes. At a constant particle size, the same filter paper will show decreased smoke penetration with decreasing flow rate.[53] This same effect was shown for

*FMTRMIT 52, op cit.

Table III. Paper-Type Filter Materials Developed for Smoke Filters through 1945

Filter Type	Manufacturer	Composition	Sheet Δ p, min H_2O	Filtering Efficiency
1B	Brown	Carbon impregnated cellulose	9.7	2.31
1M	Manning	Carbon impregnated Krafelt	12.0	2.81
2M	Manning	Krafelt, asbestos	– –	1.77
2K	Knowlton	Cotton linters, asbestos	14.1	1.90
2B	Brown	Sulfite pulp, Kraft pulp, asbestos	16.1	1.80
3	Edgewood Arsenal	Asbestos impregnated Brown Type 1	14.6	2.38
4K	Knowlton	Krafelt, asbestos	10.1	4.67
4M	Manning	Cotton linters, asbestos	10.2	3.95
Glass	Corning	Glass fibers	10.5	1.97
5A	Dexter	Rayon, cotton, Caroa fiber, asbestos	12.5	4.18
5B	Brown	Wood pulp, asbestos	13.3	4.05
6B	Brown	Sulfite and Kraft pulp, cotton, asbestos	130.7	2.43
6H	Hollingsworth and Vose	Esparto, cotton, hemp, asbestos	101.7	3.12

canisters in figure 31. However, when a pinhole was present in the filter the smoke penetration varied inversely as the airflow rate.[54]

d. Air Resistance.

The pressure drop across filter material varied with airflow, relative humidity, air pressure, and temperature. The only variable with which a designer of a collective protector smoke filter had to concern himself was airflow. In the range of airflows generally specified in collective protector design the pressure drop across a filter material varied linearly with the flow rate. This phenomenon is portrayed graphically for four filter materials in figure 32.

e. Smoke Filter Designs.

The wrapped-on type of filter was used exclusively in this country before this war. The construction necessitated by this filter had the advantage of a mechanical seal which was readily made.

There were many examples of the pad-type filter, both domestic and foreign. Figure 33 shows the four sets of four rock wool pads used as filters for the M4 Collective Protector.[43]

The Germans in their smoke filter for the 1938 Drager, 2.4-cu m collective protector canister made use of an ingenious pad arrangement to increase the filter area. Four pads of long-fiber cotton containing asbestos were arranged in two layers of two pads each. The two layers were arranged so that the air passed through them in parallel.

Figure 34 is a sketch of the Italian collective protector canister. It shows the wool resin pads used as a smoke filter.[51]

The Germans in one of their collective protector canisters (10-cu m) installed an accordion-type filter made of discs of thick, asbestos-bearing, paper-filter material.*

Pleated filters served as the smoke filters of several collective protectors. The E6R3 Tank Protector Canister (figure 35) contained a pleated filter of the same construction as the type II filter of the M11 Assault Gas-Mask Canister except that it was considerably larger in size.

The German 1943, 1.2-cu m/min collective protector smoke filter was made up of a paper arranged in vertical pleats (figure 36).[44] The paper was held in place by wire screens and the edges were sealed in a layer of asphaltic cement.

Figure 37 shows a pleated filter used in the MIT E8 Tank Protector Canister. The pleats were supported by cardboard spacers and the edges were sealed to the canister with a suitable adhesive. A skethc in figure 38 shows the construction.[56]

*FMTRMIT52, op cit.

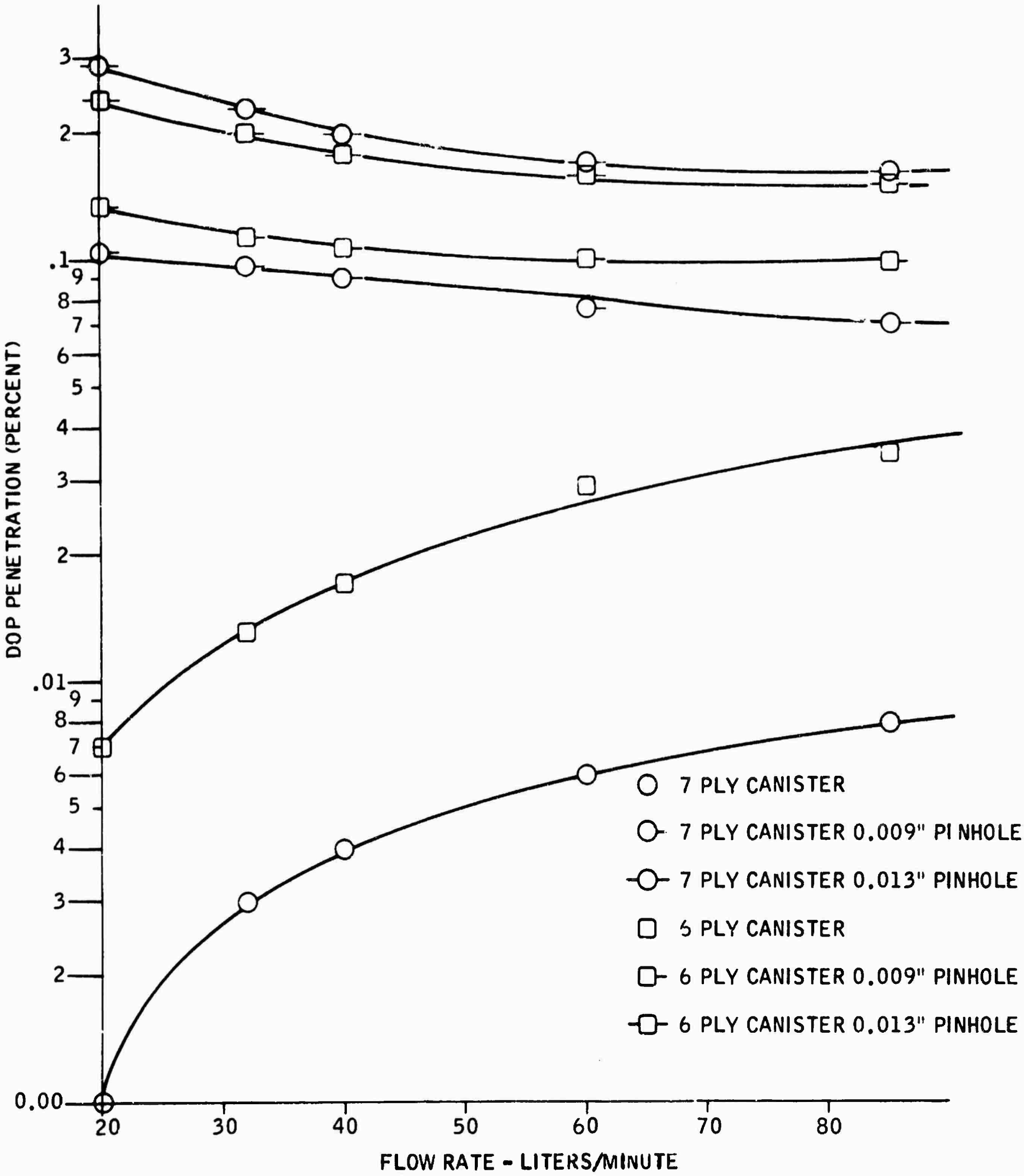


Figure 31. Effect of Velocity on 931 Meter DOP Penetrations of M10A1 Canisters with Different Amounts of Dexter Scrim Back Paper and 0.009 in. and 0.013 in. Pinholes

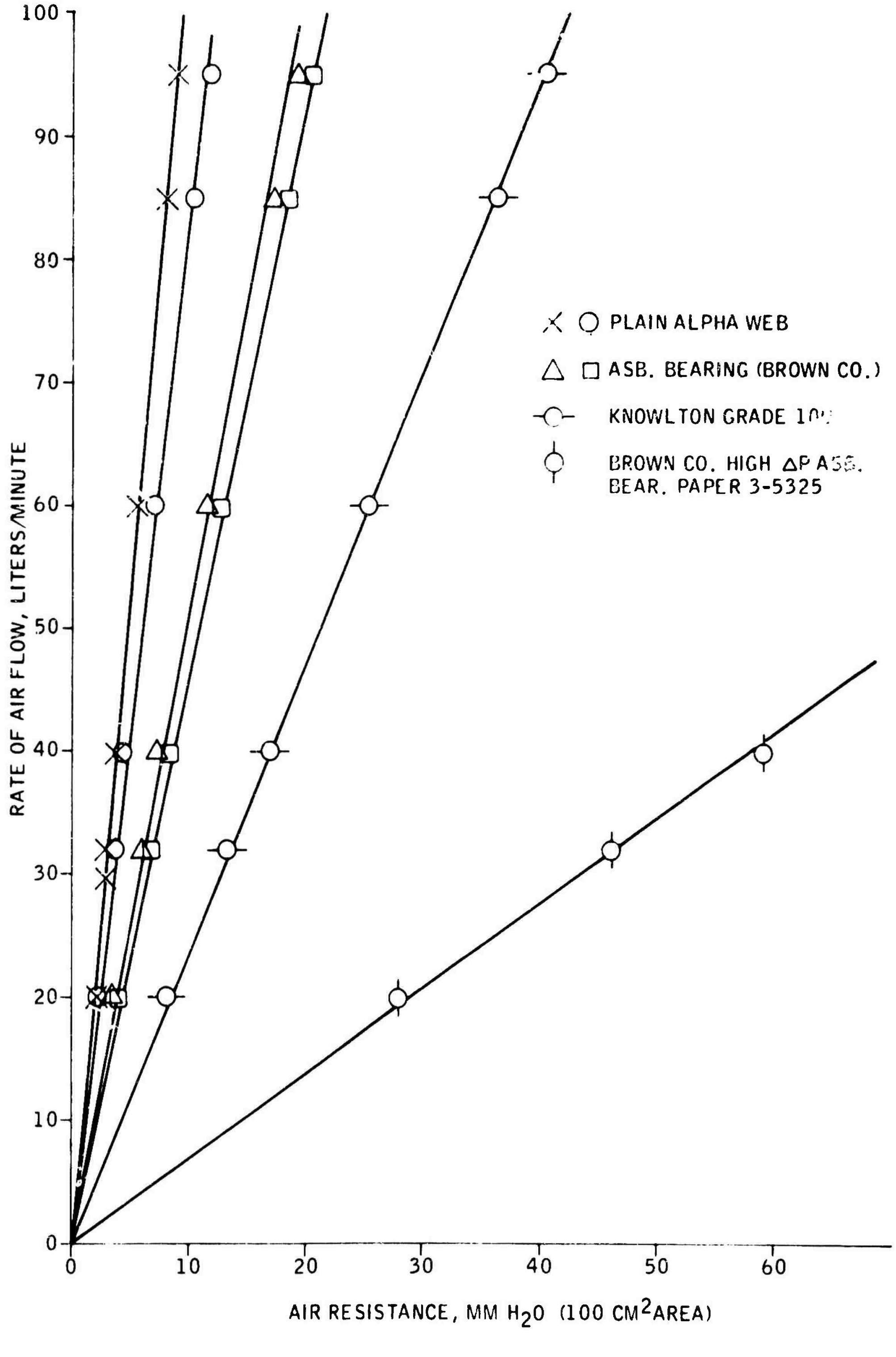


Figure 32. Air Resistance of Filter Papers vs. Rate of Air Flow

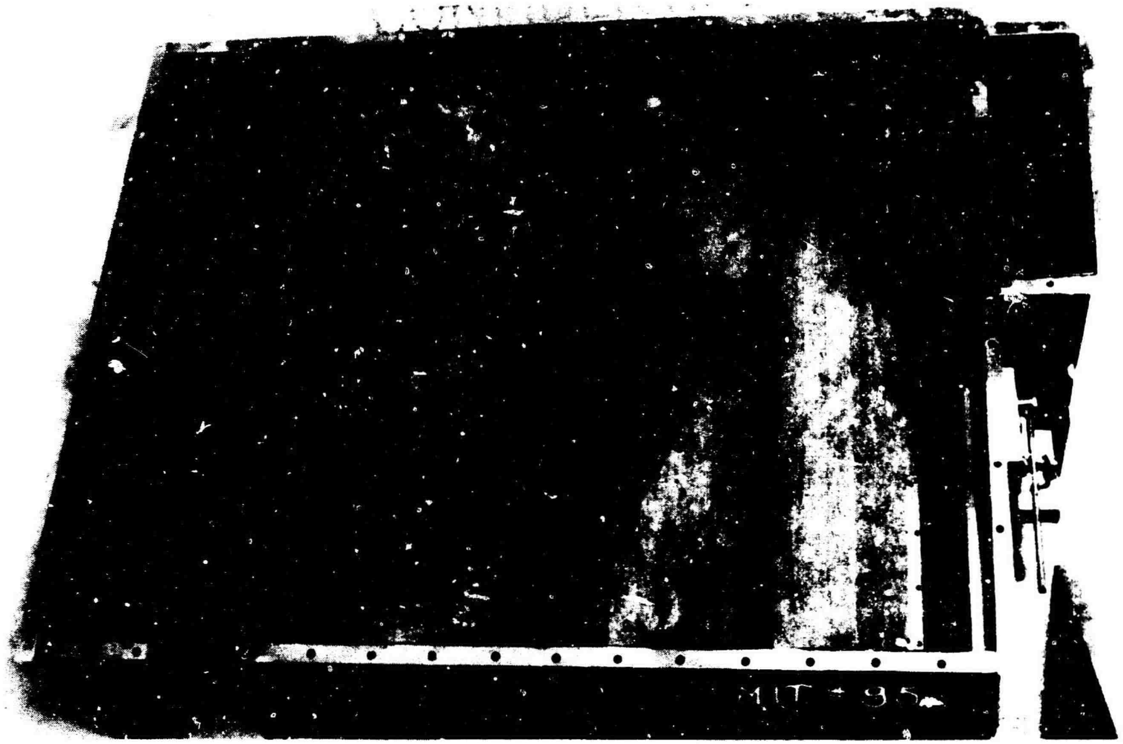


Figure 33. Civilian Collective Protector, MIT E2R4 and MIT E2R5

MIT 2389

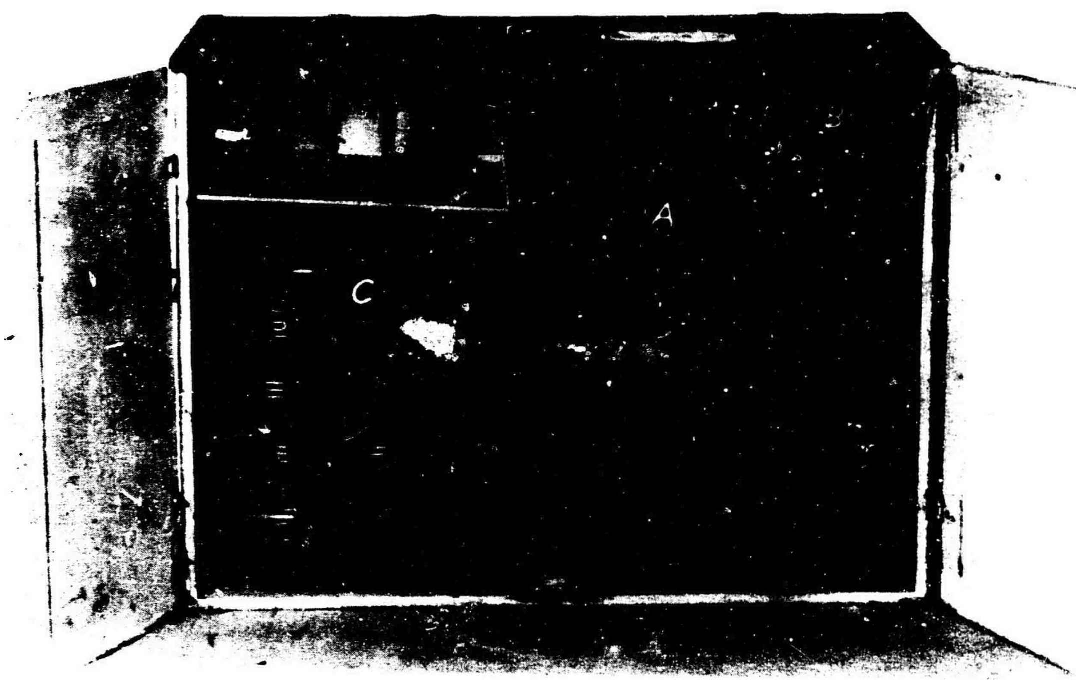


Figure 34. Box No. 2 of Italian Antigas Equipment

A. Case containing rebreather (autoprotettore) assembly; B. spare canister for rebreather; and C. copper decontamination can with pump labeled with manufacturer's name (Casarolli Brothers, Padova).

Figure 35. Tank Protector Canister, E6R3, Disassembled

A. Outer body; B. charcoal container; C. top plenum (effluent); D. bottom charcoal spacer; E. filter ring; F. 1-1/2 inch pleated paper filter; G. 2250 ml of charcoal; and H. glass wool and resin wool pads.

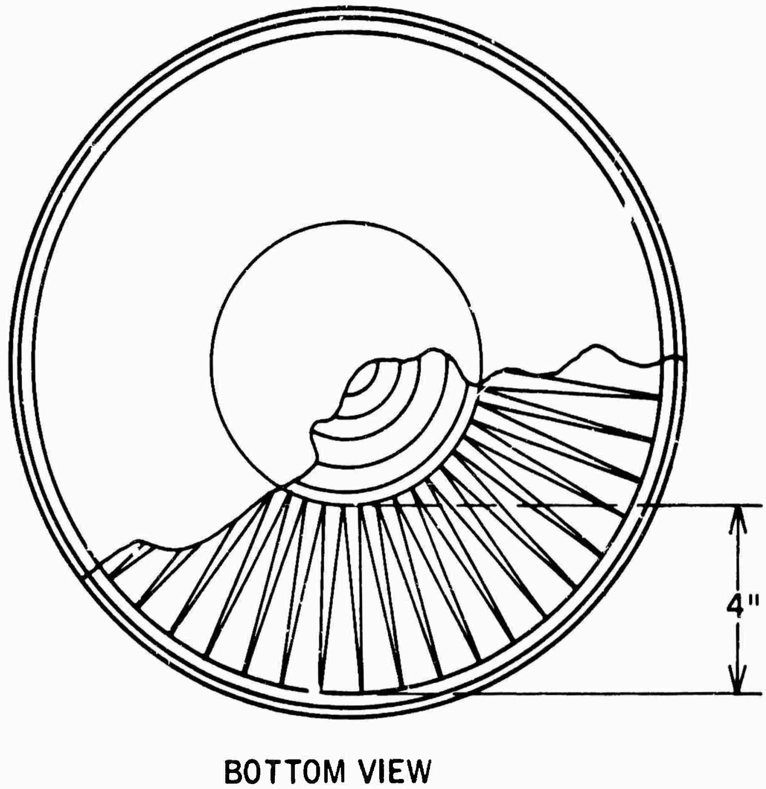
3. Dust Filter Design.

Dusts were generally composed of much larger particles than smokes.[48] They could therefore be filtered more easily with relatively inexpensive and simply constructed equipment which could be readily replaced. Since this dust would tend to clog smoke filters and render the collective protector ineffective, dust filters were used in many instances to protect the smoke filter from plugging.

The Germans employed dust filters of various sizes to preclean the air of their collective protectors (figures 39 to 42). The expanded metal pre-cleaner was dipped in oil before use and removed about 54% of the influent dust. The cotton batting of the wedge-shaped filter took out about 24% of the dust. About 18% of the influent dust settled out on various parts of the filter assembly, while 4% penetrated the filter.*,[44]

The M4 Collective Protector was the first American collective protector to employ a dust filter. Initial designs simply called for a pad of rock wool placed in the canister inlet. Subsequent models were supplied with a commercial filter called the dustop.[43]

*FMTRMIT52.op cit.



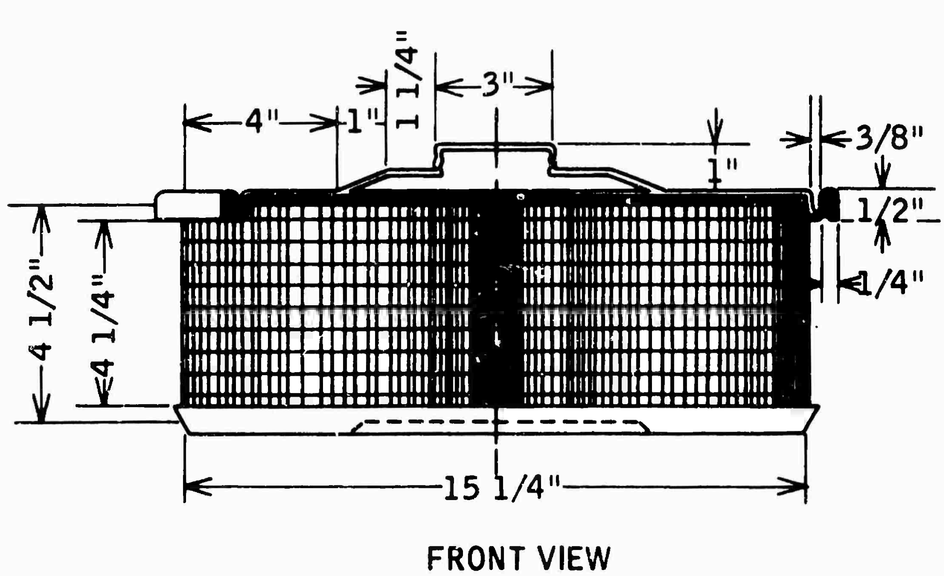


Figure 36. German 1943 1.2 cu m/min Collective Protector Smoke Filter No. byd S2925

Figure 37. Filter Section of MITE8 Tank Protector Canister

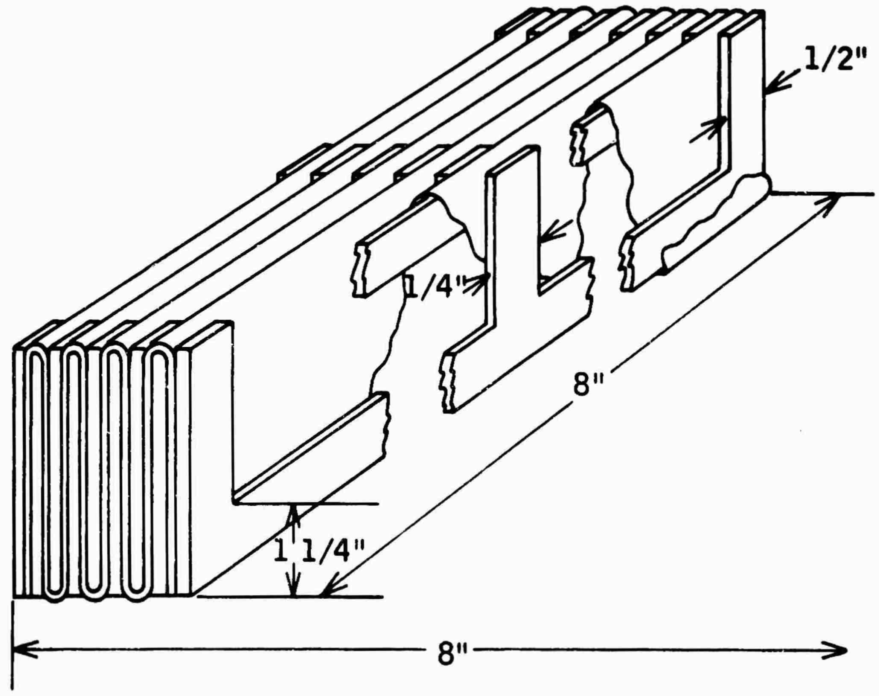


Figure 38. Straight Pleat Filter with Cardboard Dividers

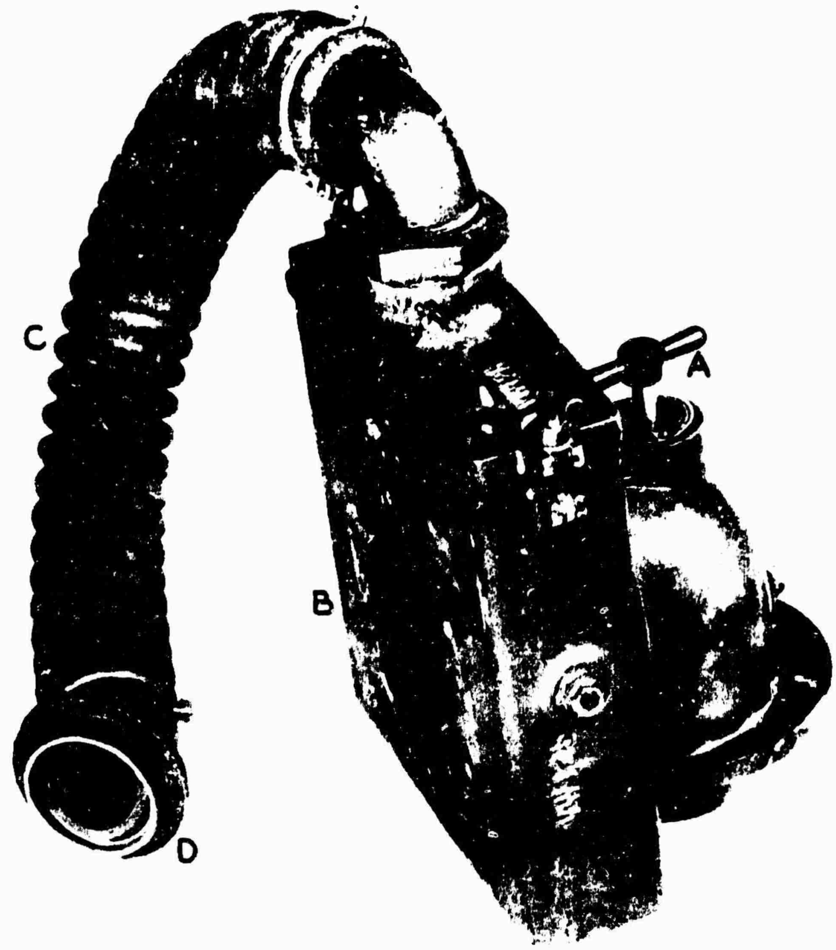


Figure 39. Complete Assembly of German 1.2 cu m/min Collective Protector with Dust Filter and Connecting Tubing

A. "Quick-opening" type inlet valve; B. outer casting of dust filter; C. stockinette-covered, rubber connecting tubing; and D. sheet-metal adaptor to top threads of smoke filter.

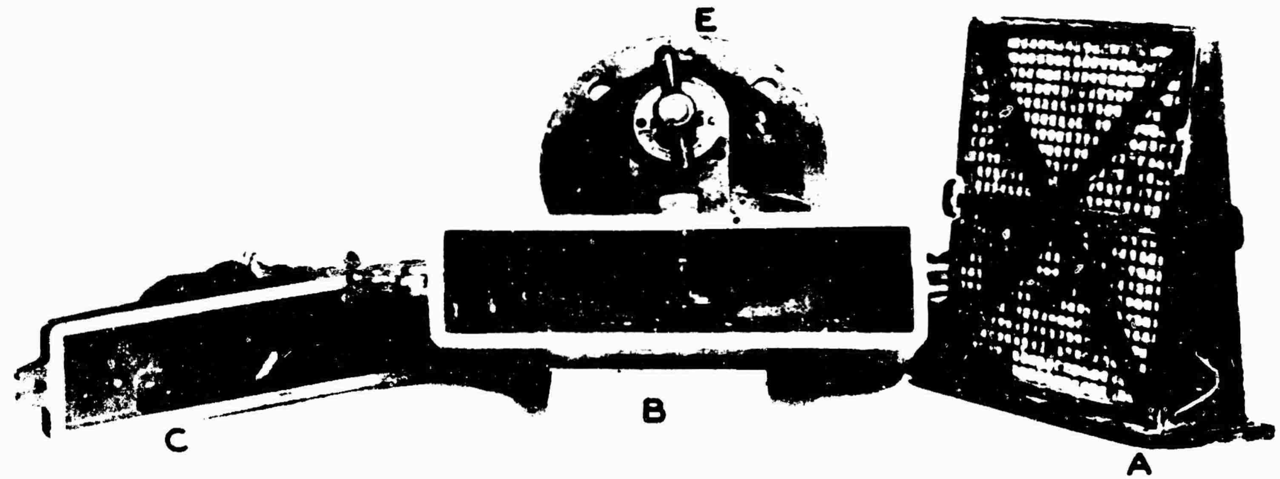


Figure 40. Disassembled View of Dust Filter of German 1.2 cu m/min Collective Protector

A. Wedge-shaped filter-material holder; B. outer body of dust filter; C. top cover plate; D. expanded-metal precleaner in place in the filter casing; and E. "quick-opening" valve.

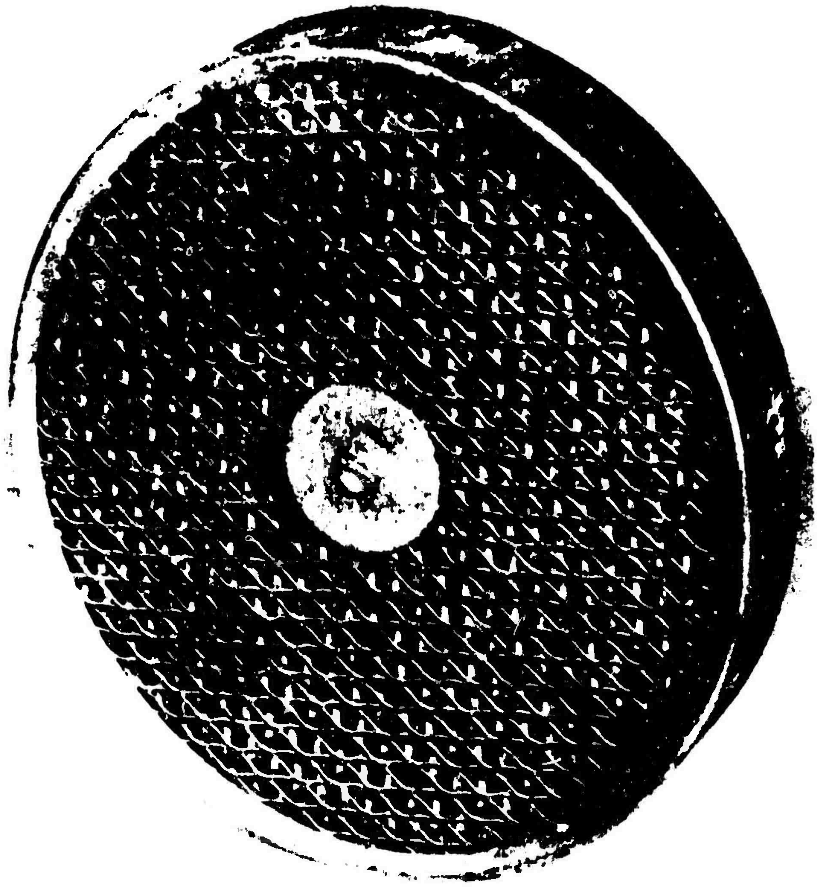


Figure 41. Metal Precleaner from Dust Filter of German 1.2 cu m/min Collective Protector

Figure 42. German 1.2 cu m/min Collective Protector

Because road dust represented a serious problem for tanks, considerable work was done to develop a suitable dust filter for the tank protectors. The large tank protector was equipped with a Rotoclone blower which was designed to separate dust in addition to performing normally as a blower. Its efficiency varied from 60 to 80% depending on the size and type of dust used. A dust filter of a rock wool pad and glass storage battery mat was built in as an integral part of the tank protector canister.[56]

In the development of both the above-mentioned collective protector and of the E21R2 Facepiece Protector, many different dust filters were developed and tested. Air cleaners used in automobiles were found to be inefficient; the generally-used commercial air filters were practically worthless. Filters made of rock wool proved to be very satisfactory dust filters, however, they could not stand rough handling tests and were rejected on that basis.

The dust filter chosen for the facepiece protector proved to be very good in actual field use. It consisted of two Aeroter units which were no more than well-designed miniature cyclone separators and a pleated felt filter. The Aeroter units removed about 90% of the dust and the pleated felt removed about 100% of the rest. The fine dust penetrating the Aeroter unit had five times the plugging effect of the original dust and although the Aeroter unit removed 90% of the original concentration it increased the pleated felt filter life by only a factor of two.[30]

The navy collective protector was built with a prefilter which removed dust and moisture.*

D. Blower Design.

1. General.

A theoretical approach was impractical in blower designs since there were at least 14 variables to be considered. Most blower design work was empirical (based on previous experience or on experimental work).[57]

Ordinarily a collective protector designer chose, from a manufacturer's catalog a suitable blower which would operate well under design conditions of airflow and static pressure requirements. In some cases this could not be done because of special circumstances. For example, it was found that the small blowers chosen for the facepiece protector were quite inefficient. Similarly, the blower manufacturers did not make aluminum blowers which were suitable for the field collective protector.

No attempt is made to give a complete presentation on blower design in this monograph. An indication of the methods followed in some investigations made in connection with collective protector desing are given.

2. Fan Laws.

A proper understanding of the fan laws which apply to all centrifugal machinery was not only needed for blower design work but for a proper conception of blower operation. For

*FTP 222. Navy Defensive Chemical Warfare Manual. 1944.

a given fan operating under a given set of conditions (gas of same density, same system, or equivalent) the laws are as follows:

1. Capacity is directly proportional to speed.

2. Pressure head is directly proportional to the square of the speed.

3. Horsepower is directly proportional to the cube of the speed.

4. Pressure head is directly proportional to the square of the capacity.

5. Horsepower is directly proportional to the cube of the capacity.

6. Horsepower is proportional to the three-halves power of the pressure head.

3. Fan Design for Facepiece Protector.

A small vacuum cleaner blower was used in the first models of the facepiece protector. These units proved to be only 38% efficient. To increase the efficiency of the blower several variables of blower design were investigated:

For the housing

1. Housing thickness
2. Cut-off clearance
3. Cut-off radius
4. Wheel exposure
5. Inlet diameter

For the wheel

1. Wheel thickness
2. Blade curvature
3. Inlet diameter
4. Wheel taper
5. Number of blades

Figure 43 defines most of these terms.

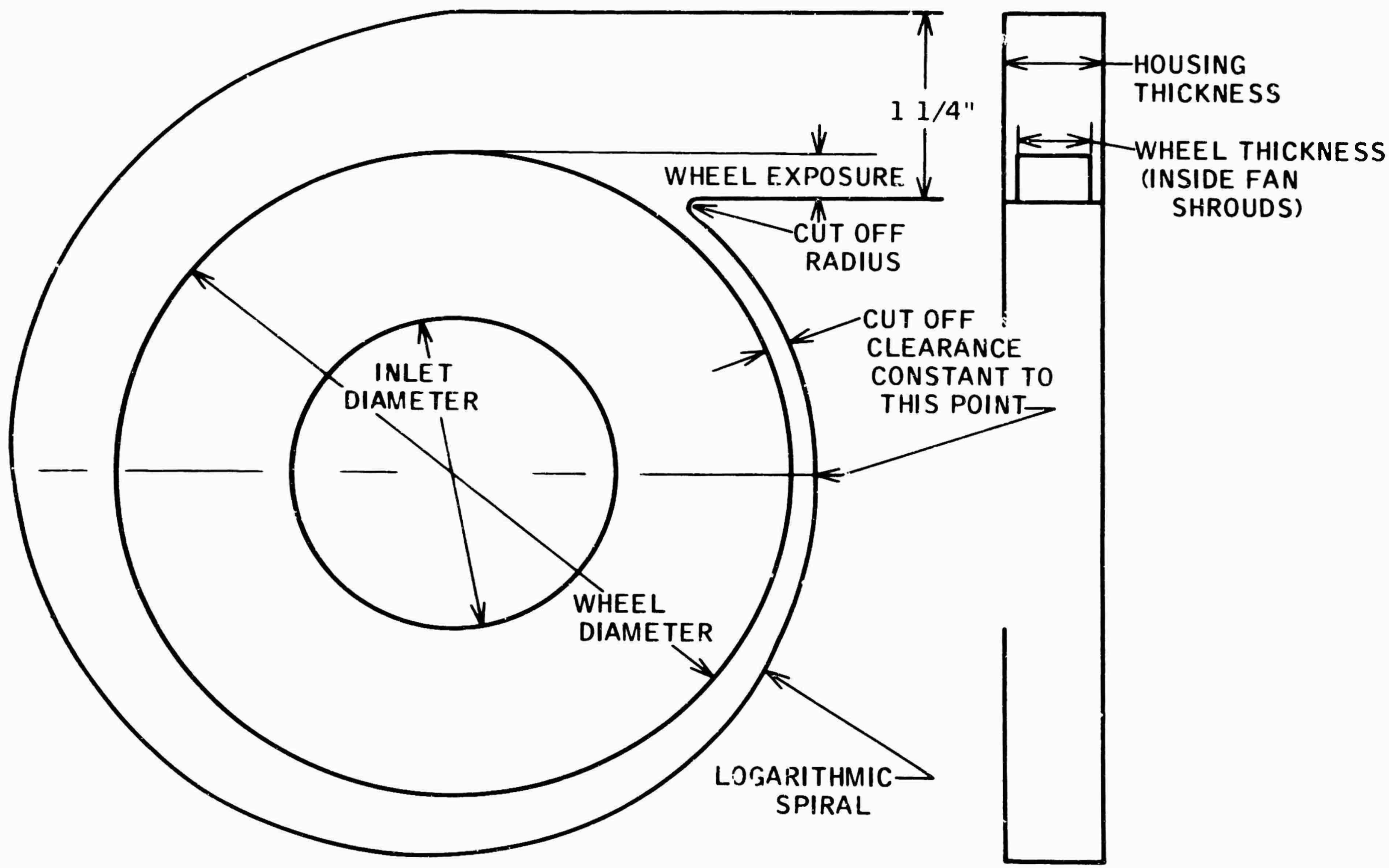


Figure 43. Location of Variable Dimensions of Fan Housing

It was found that changing most of the variables had little or no effect on the blower efficiency. The efficiency of the blower was increased from 38% to 53% by choosing the optimum cut-off clearance, fan housing thickness, and wheel exposure.[57]

A similar investigation was made when the only aluminum blower available would not meet the design requirements of a field collective protector. Six different spiral casings and the manufacturer's aluminum scroll were tried in conjunction with eight different fan wheels. It was possible to increase the static pressure developed by a fan delivering 300 cu ft/min of air from 5.4 to 8.0 in. of water by choosing the best combination of casing and fan (impeller).[42]

E. Drive.

There were three types of drive in general use on the blowers of collective protectors: (1) hand or foot drive; (2) gasoline engine; and (3) electric motor.

Foot drive using a modified bicycle crank mechanism was used on some collective protector installations. At least one reference appeared in foreign literature of such a drive (figure 44).[5] In the development of the M4 collective protector a similar foot drive was tried, but it required more exertion than the hand drive. Further work along those lines was therefore stopped.[43]

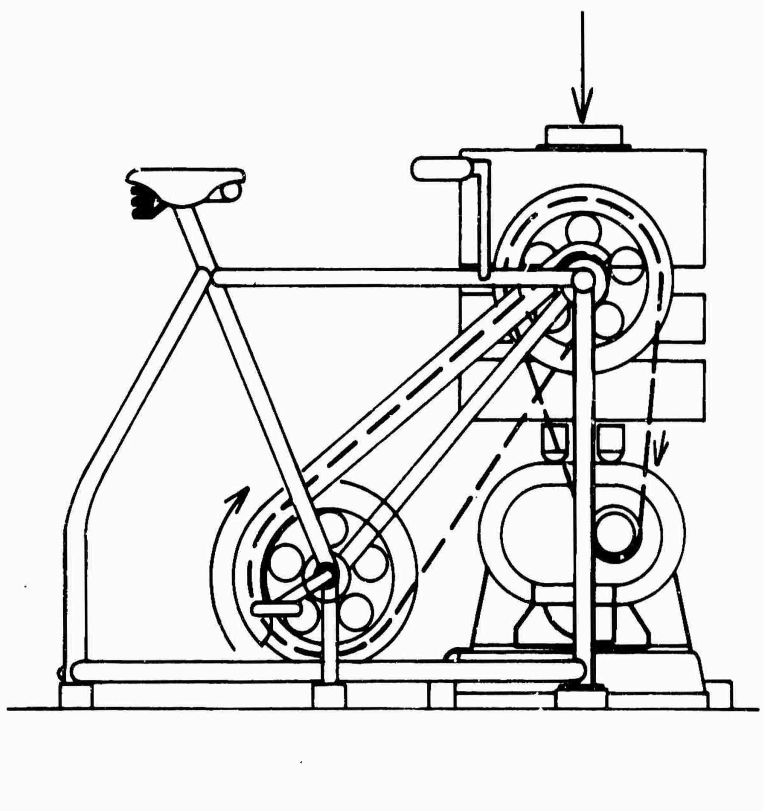


Figure 44. Foot-Driven Ventilation Apparatus

Hand drives had quite extensive utilization for collective protectors. The reason for this was that electrical or mechanical power failures would not influence the operation of a hand-driven collective protector.

Figure 45 is an example of an Italian collective protector provided with hand drive.[51] A German hand-driven blower for the 1.2 cu m/min collective protector is shown in figure 46. A view of the gear box, which increased the hand cranking speed by a factor of 68, is also shown in this figure. Figure 47 lists a set of blower characteristics at various handcrank speeds showing the effect of handcrank speed on the operation of the collective protector.[49]

American practice was to have the handcrank as an alternate drive in conjunction with either a gasoline engine or an electric motor. Thus the small field collective protector, in the course of its development, included a hand drive in addition to a gasoline engine drive (figure 48).[18]

The civilian collective protector was equipped with an electric motor having two shafts, one ran at 3600 rpm while the other was reduced through a gear box to 40 rpm. A handcrank on the low-speed shaft could operate the high-speed shaft. One man turning the handle could deliver 100 cu ft/min of air for 15 min with only slight fatigue. Figure 49 is a plot of crank speed versus the air delivered in cu ft/min by the hand drive.[43]

Small one-cylinder gasoline engines powered the blowers of a number of collective protectors. Their advantage lay in the fact that electric power failures would not influence them. Their exhaust fumes, however, presented a problem because of the air pollution caused when the gas engines were operated in a confined space.

Because of their quiet, reliable, and fume-free operation, electric motors were chosen to drive collective protector blowers whenever possible.

F. Test Methods.

1. Collective Protectors M1A2, M2, M2A1, M2A2, and M3.

In general, the above units are an assembly of air ducts, valves, a motordriven blower, and a canister. The inspection and test of the above units are divided into the inspection of the collective protector less canister and of the canister.*

a. Collective Protector Less Canister.

The collective protector less canister is tested for its mechanical functioning and constructional details to insure that the correct amount of air is passed through the canister and that the entire assembly meets the requirements of the applicable drawings. The inspection procedure for insuring compliance with the applicable specifications is amply covered in Standard Inspection Procedure 441.

*Standard Inspection Procedure 441. 1 September 1944.

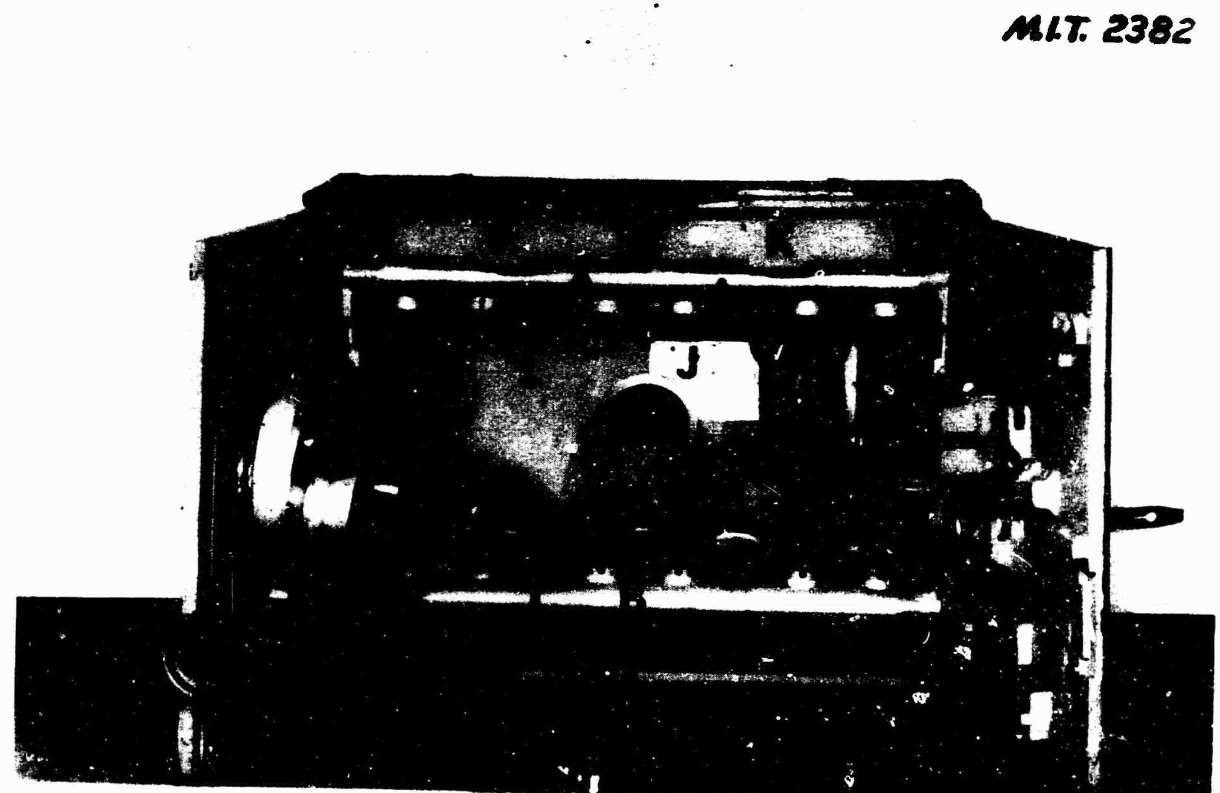


Figure 45. Box No. 1 of Italian Antigas Equipment

A. Air outlet pipe; B. air inlet pipe; C. bottom canister support; D. blower; E. rotometer; F. inlet adapter; G. elbows (inlet and outlet); H. locking levers; I. tool for locking levers; J. instruction card for assembly; K. drawers for small parts; L. top canister supports; and M. connectors.

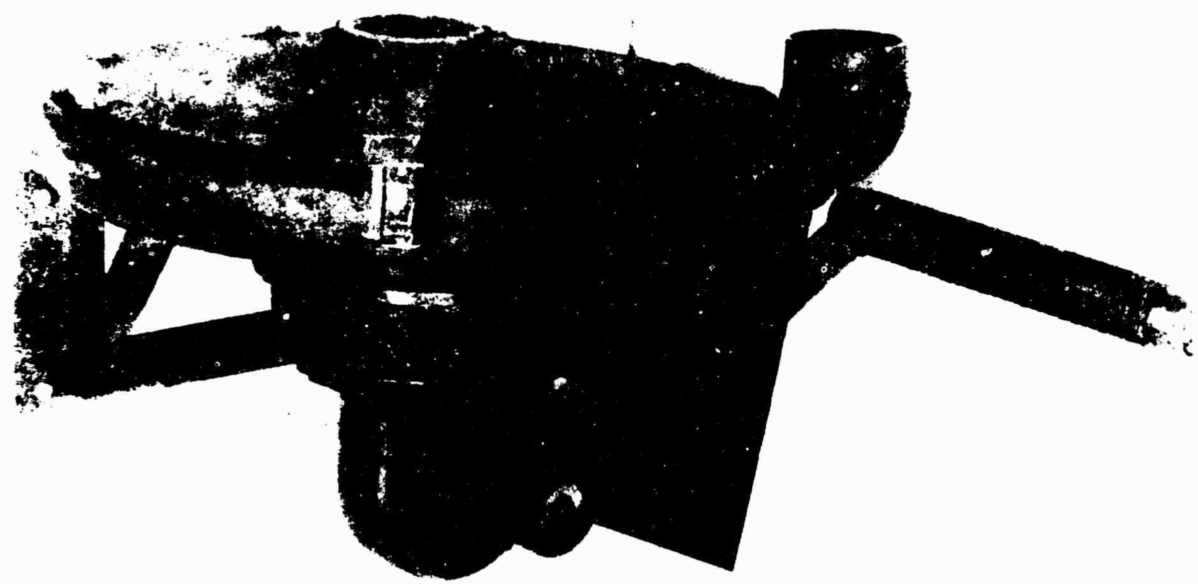


Figure 46. Blower and Gear Driving Mechanism of the 1.2 cu m/min Collective Protector

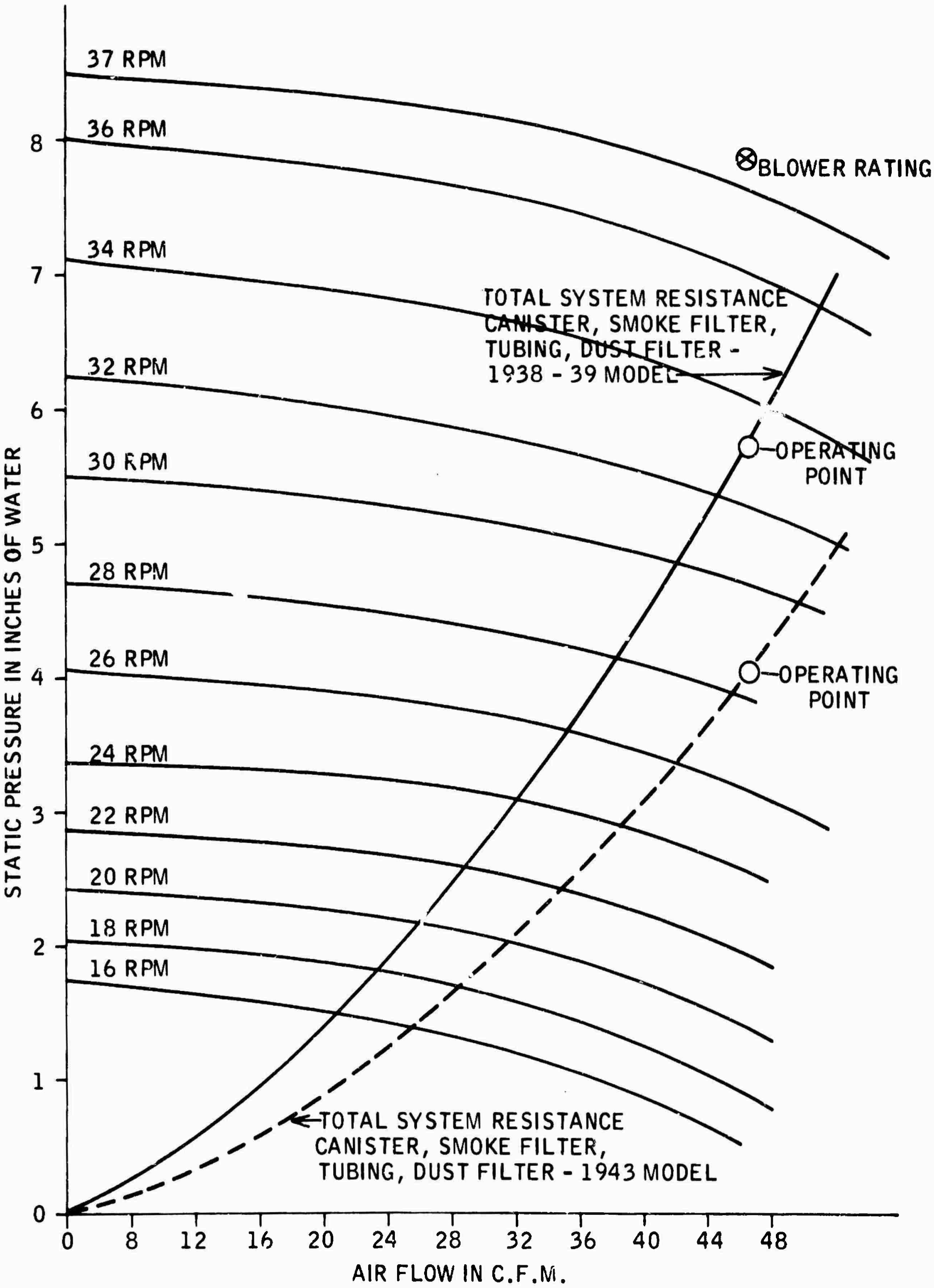


Figure 47. Blower Characteristics and System Resistances of German 1.2 cu m/min Collective Protector

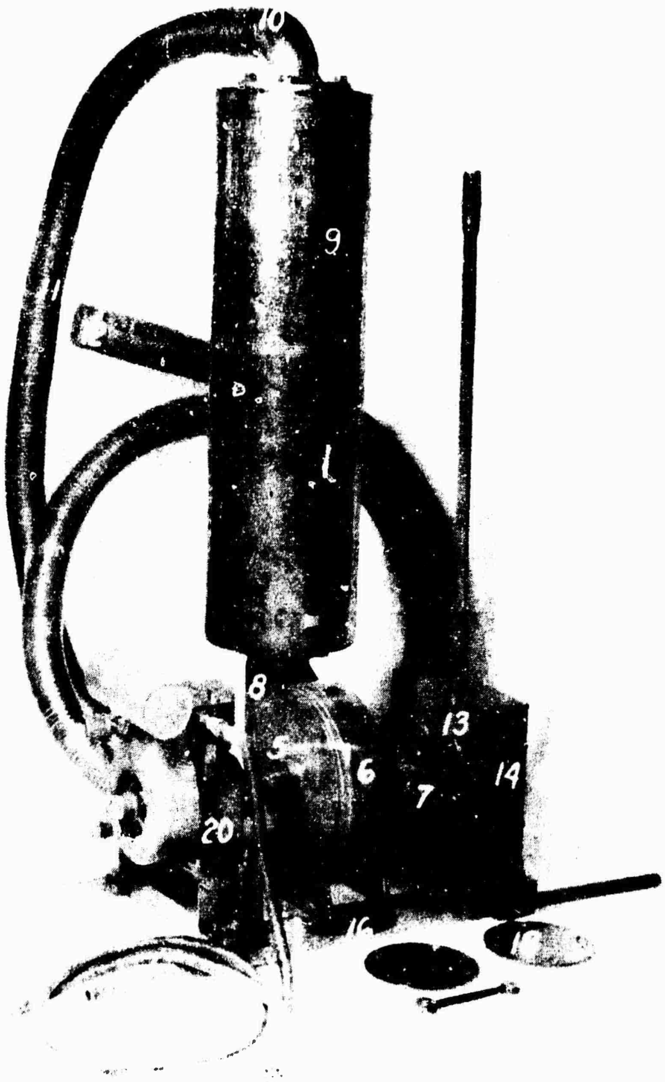


Figure 48. Collective Protector E8R6

(1) Gasoline engine; (2) fuel tank; (3) foot pedal; (4) flexible exhaust tubing; (5) engine driving clutch; (6) blower; (7) screened blower inlet; (8) blower outlet; (9) canister; (10) canister elbow; (11) flexible metallic air hose; (12) screen; (13) clutch; (14) hand drive; (15) hand lever; (16) base; (17) carrying handles; (18) blind flanges; (19) wrench; and (20) lubricating oil filling plug.

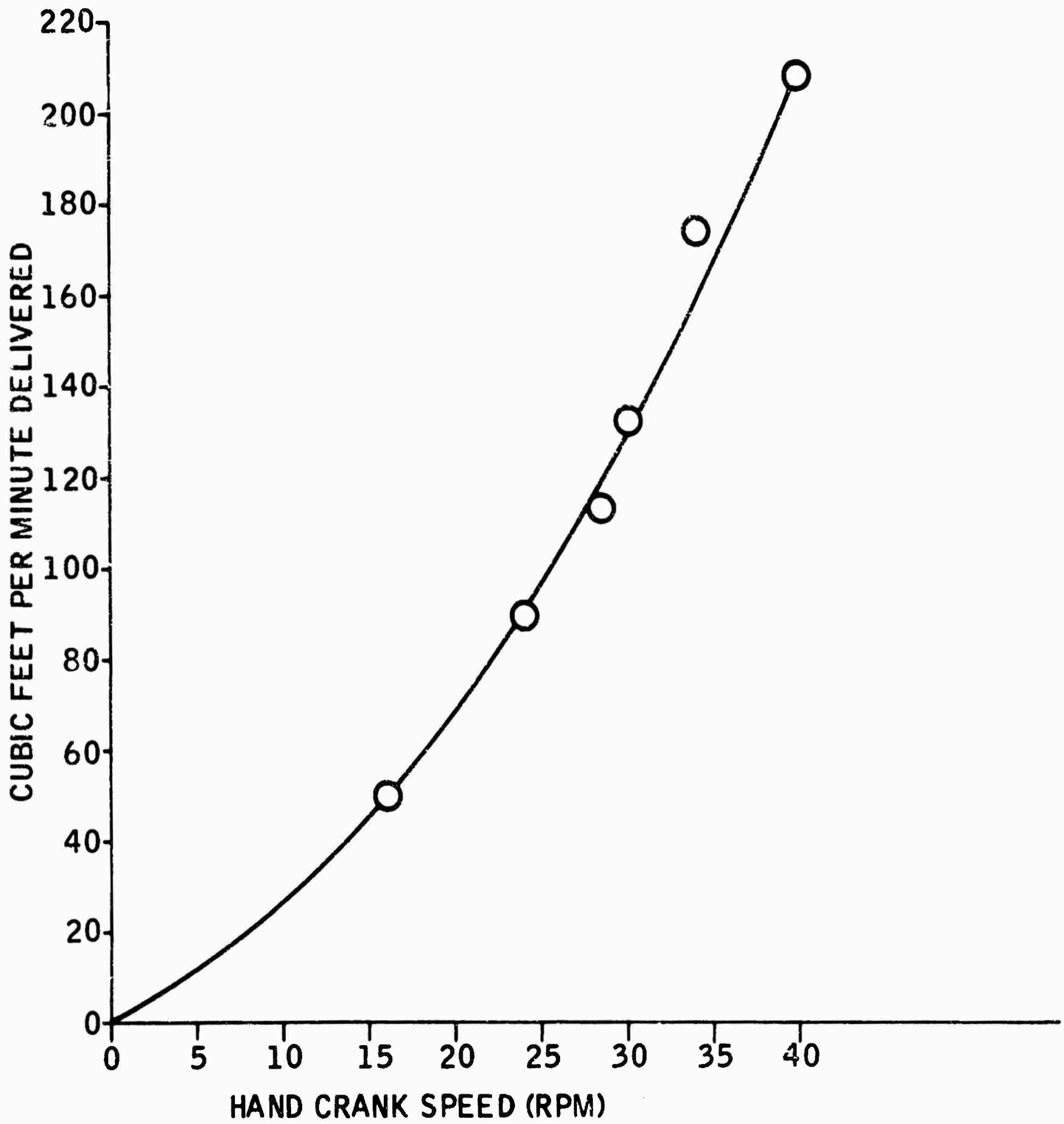


Figure 49. Protector, Collective Hand Crank Operation (Filter, 5 Pads Rock Wool
Δ P at 850 cm/min = 0.50 in. N_2O)

b. Collective Protector Canisters M1, M2, and M3.

These canisters are composed of a group of air-purifier tubes supported and spaced in a steel shell.

The inspection and test of the subassemblies and final assembly of the canister are covered in the applicable specifications, Standard Inspection Procedure 451 and CWS Directive No. 82A, Directive for the Operation of Resistance Indicator E7R4.

The efficiency of the collective protector canister against the various war gases and smokes is determined by chemical laboratory tests.*

(1) Phosgene Test versus Air Purifier Tube, CWS Pamphlet No. 2, Part III, Section A: Phosgene Tests on Chemical Containers.

The specific purpose for performing the phosgene test before the air purifier tubes are assembled in the canister is to insure that the tubes have been filled properly and are free from mechanical defects. The Whetlerite used in the tubes has been tested previously for its phosgene life so that the tube will meet specification, provided there are no defects. In addition, one tube out of every alternate group of 17 tubes is rough handled to determine the compactness of filling. If the packing is imperfect, the Wheterite will settle in the chemical container and the capacity of the tube for phosgene will be below specification requirements. Drawings and specifications** are available for the manufacture of the rough-handling machine, and the method of conducting the rough-handling test is given in a CWS Specification.† The governing principle of this test is the direct measurement of the capacity of the collective protector chemical container to remove phosgene from the air passing through it. The test is conducted by passing air of 50% relative humidity and of a specified phosgene concentration through the chemical container at the specified flow rate. The time, in minutes, that the chemical container prevents the passing of a detectable amount of phosgene is a measure of the life of the chemical container.

(2) Methylene Blue Test on Air Purifiers, CWS Pamphlet No. 2, Part III, Section E.

The specific purpose of this test is to insure that the filter material has been correctly attached and properly secured in the canister filter. The filtering efficiency of the filter is determined by passing an aerosol of methylene blue dye through the filter at a definite rate of flow and measuring colorimetrically the percentage of methylene blue penetrating the filter.

The apparatus consists essentially of a device for atomizing a solution of methylene blue and mixing the mist with air which vaporizes the water in the droplets, leaving a smoke, or aerosol, of particles of methylene blue (MB). The smoke is drawn through the filter which is being tested at a definite flow rate and part of the effluent from the filter passes through a test

*Chemical Warfare Service Pamphlet No. 2 PIII, Sections A, E and Temporary Change T-3002, 3 March 1945 on Specifications 197-54-47, 197-54-80, 197-54-107, 22 April 1944 describe the various tests.
**CWS Tentative Spec. No. 79, 5 Aug 1942.
†CWS Spec. No. 197-54-47B.

strip of filter paper on which the methylene blue which penetrated the filter is deposited. The original MB smoke is sampled and its concentration is compared with that penetrating the filter by matching the intensity of the stains produced by the methylene blue on the test strips.

(3) Methylene Blue Test on Canisters: Directive for Operation of Methylene Blue Test Apparatus E8R1 for Testing Collective Protector Canisters M1, M2, and M3.

The object of this test is to make sure that neither the air purifier nor the canister parts have been damaged during the final assembly and to determine the penetration of methylene-blue smoke through the air purifier filters. The filtering efficiency of the canister is determined by passing an aerosol of methylene blue through the filter at a definite rate of flow and measuring colorimetrically the percentage of methylene blue penetrating the filter. The method is not a completely independent test as is the case of the methylene-blue test on air purifiers, but is standardized by the use of filters and pads of filter paper, the penetration of which have been determined on methylene-blue test apparatus E5R2.

The methylene-blue smoke is formed by spraying a 1% aqueous solution of methylene blue into a duct which forms the intake of a blower supplying air at the rate of 200 or 50 cu ft/min to the canister under test. The mist from the spray nozzle passes a series of baffles to remove the coarse droplets before the mist passes through the blower. The moisture evaporates from the mist as it passes through the blower, resulting in an aerosol of fine dry methylene-blue particles which is piped through the canister. The rate of flow is measured by an orifice in the pipeline. A small sample of the smoke which passes through the canister is drawn through a strip of test paper. Similarly a small sample of the smoke which passes into the canister is drawn through a pad of standard filter paper and then through a strip of test paper. By comparing the intensities on the two test strips it is possible to determine the relative penetration of the canister.*

2. Collective Protectors, M4 and M4A1.

The M4 Collective Protector or the multiple unit (M4A1), which may be operated as a single unit by attaching the head of an M4 unit, is tested before acceptance for mechanized functioning, volume of air, leakage, and smoke and gas protection after rough handling.

a. Mechanical Functioning.

The completely assembled collective protector is connected to a source of power, and the motor driving the blower operated for 10 min. With the motor running, the

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*Protector, Collective, M1A2, CWS Spec. No. 197-54-339,
Protector, Collective, M2, CWS Spec. No. 197-54-129,
Protector, Collective, M2A2, CWS Spec. No. 97-54-289,
Protector, Collective, M3, CWS Spec. No. 97-54-224,
Canister, Collective Protector, M1, CWS Spec. No. 197-54-47B,
Canister, Collective Protector, M2, CWS Spec. No. 197-54-107A,
Canister, Collective Protector, M3, CWS Spec. No. 197-54-80,

mechanical controls and regulating devices are operated. The results are observed for compliance with the individual and collective functional requirements of the respective unit assemblies.

b. Volume of Air and Leakage.

(1) Motor Drive.

The volume of air and leakage may be obtained simultaneously by connecting an 8-in. diameter sheet-metal pipe containing an orifice plate with an opening of 4.8 in. in diameter to the inlet of the collective protector and by connecting a 6-in. diameter sheet-metal pipe containing an orifice plate with an opening 4.8 in. in diameter to the outlet. With the motor operating at a fan speed of 3450 rpm the flow in and out of the collective protector is measured. The difference between the outflow and the inflow in the collective protector is termed "leakage" and is expressed as percent of outflow. It is important that the outflow of the collective protector be within the limits of the applicable specification and that the leakage does not exceed the specification, otherwise there will be excessive recirculation of the air in the gasproof shelter and it will be impossible to maintain the sl lter pressure.

(2) Hand Drive.

The M4 Collective Protector is equipped with a crank and gear-head motor so that the blower may be operated by hand in case of an electrical failure. When operated by hand at a crank speed of 22 rpm the fan speed should not be less than 1850 rpm and the output should be 90 ±9 cu ft/min of air against a static head of 0.2 in. of water.

c. Smoke and Gas Protection After Rough Handling.

The efficiency of the M4 Collective Protector against the various gases is measured by subjecting all collective protectors in the first shipment from any manufacturer and 10% of all subsequent shipments to a rough-handling process followed by the determination of the smoke protection by means of a methylene-blue aerosol test and the determination of the gas protection by the use of a CN capsule. In addition, 1% of the collective protectors are tested for their total protection against phosgene.*

(1) Rough Handling Test.

This test consists of clamping the protectors on a rough-handling machine which will give sharp drops of 13/16 ± 1/16 in. at a rate of 215 ± 15 drops/min for a period of 10 min. One such machine has been constructed and used. It is designated as E4 Rough Handling, Machine. If it is not packed tightly and evenly in the purified tubes, the adsorbent will settle and the capacity of the collective protector for adsorbing phosgene will be below specification requirements and the vapor from the CN capsule will penetrate.

*CWS Directive No. 171.

(2) Smoke Protection.

After rough handling, all samples are tested for methylene-blue smoke penetration in accordance with a CWS Directive.* In principle, this test is essentially the same as that described under methylene-blue tests on M1, M2, and M3 Collective Protector Canisters.

The ability of the M4 Collective Protector to protect against toxic smokes is measured by means of a penetration test using nontoxic methylene-blue smoke. The methylene-blue smoke is formed by spraying a 1% aqueous solution of methylene blue into a preheated air stream in a drying chamber in which the liquid droplets are evaporated, leaving dry, solid, air-floated particles of methylene blue. The greater portion of the air in the drying chamber is drawn through the collective protector by means of the blower attached to it. A small sample of this air, which has penetrated the canister, is taken from the effluent pipe of the collective protector and drawn through a paper-strip holder. The remainder of the air from the drying chamber is drawn through a standard filter of a definite number of plies of filter paper of 100 sq cm area. It is then passed through a paper-strip holder similar to the one on the effluent side of the collective protector. Similar paper test strips are placed in the two-strip holders to collect the smoke penetrating the collective protector canister and the standard filter, respectively. The airflows through the two test strips are the same (32 l/m), thus, a comparison of the color intensities of the strips after a 5-min period of operation, with the standard pad penetration corrected for the blocking effect of a 5-min test, gives the reiation between the penetration of the collective protector and the standard filter.

3. Gas Protection.

a. CN Test.

After the methylene-blue test, all collective protectors are tested for leaks through the gasketing and channeling through the adsorbent bed by setting up the collective protector with a conveniently located single air inlet 50-ft long and operating the protector to deliver air at its rated capacity into an enclosed space. One CN capsule is evaporated at a rate of 0.5 to 1.0 gm/min on a hot plate at the entrance of the pipe. No odor or lacrymation should be detectable to unmasked observers stationed within the enclosure.**

b. Phosgene Test.†

The object of the phosgene test is to make certain that the collective protector has been filled properly and that the total phosgene adsorptive capacity meets the requirements of the applicable specifications.

*Outline for Performing Methylene Blue Smoke Test on Protector, Collective, M4. CWS Directive No. 254.

**US Army Spec. No. 97-54-69.

†Directive for Phosgene Test on Collective Protectors M4 and M4A1. CWS Directive 171.

The test is conducted by passing air containing a concentration of approximately 10 mg of phosgene per liter of air into the canister intake while the canister blower is operated under normal motor operation. The blower draws the gas-air mixture into the canister and into contact with the charcoal filling. A sample of the effluent air from the canister outlet is bubbled at a definite rate of flow through a slightly basic solution of methyl red indicator. The weight of phosgene adsorbed by the collective protector until the indicator changes from yellow to red is determined by weighing the phosgene supply (phosgene cylinder) before and after testing and taking the weight differential.*

c. Protector, Facepiece, Three-Man, E22.

The facepiece protector is an apparatus designed to remove toxic gases and smokes from air and to supply the purified air to personnel whose activities are confined to small areas. Purified air is blown through the hoses (attached to the canister nozzles) to the light-weight facepieces worn by personnel. Each three-man facepiece protector can supply air for two or three persons and consists essentially of an air-purifier assembly, inlet duct, 3/4-in. flexible hose assembly, facepiece assembly, cable assembly, and accessories.

Acceptance tests are made on the following components of the facepiece protector E22: (1) air purifier; (2) canister; (3) corrugated hose; (4) facepiece.

(1) Air Purifier.

The air purifier assembly contains a canister, dust filter, and blower precleaner assembly. The air-purifier assembly furnishes the air to the facepiece assembly. It is imperative that the amount of air furnished by the air purifier be within the limits of the specification to insure adequate air to the facepiece and at the same time not an excess which would reduce the life of the air purifier to war gases and make the wearer uncomfortable.

An orifice or nozzle-type flow meter, calibrated in cu ft/min, is connected through straight pipes of suitable size to each of the canister nozzles. A tap is provided in the pipe approximately 6 to 8 in. from the end of the nozzle to obtain the static pressure at the nozzle. A globe or butterfly valve is located in the pipe upstream from the flow meter to adjust the static pressure at the nozzle. The valve is adjusted to give a static pressure at the nozzle of 3.1 ±0.1 in. of water at 5.0 ±0.1 cu ft/min. The blower of the air purifier is operated at 24.0 ±0.1 volts. When a steady state of operation is obtained, measurements are made of the voltage, amperage, and airflow.**

(2) Canister (For Three-Man Facepiece Protector, E22).

The above canister is a filtering unit, so designed that when contaminated air is passed through it, the gases, vapors, and toxic smokes are removed. It is composed of a shield-type filter of type 6 filter material and a 2-1/8-in. charcoal bed containing 2235 ml of 20-30 mesh, grade 1 ASC charcoal.

*Protector, Collective, M4, CWS Spec. No. 197-54-248; Canister, Collective Protector, M4A1, CWS Spec. No. 197-54-250A.

**Air Purifier (For Three-Man Facepiece Protector, E22). CWS Spec. No. 197-54-418.

Tests made on this canister include the determination of the volume of the filling charcoal moisture content, airflow resistance, smoke penetration, rough handling, and phosgene adsorption.

The details of determining the volume of the filling and the charcoal moisture content are given in the applicable specification.

(a) Canister Airflow Resistance.

The resistance of the canister is specified in order to insure satisfactory operation of the E22 Three-Man Facepiece Protector. If the air resistance is too low, faulty filling is indicated and the canister protection performance under service conditions will probably be poor. If the resistance of the canister is too high, the quantity of air delivered will be too low for adequate protection and the temperature rise in the air stream will be unnecessarily high. The resistance of the canister is measured by determining the pressure required to force air at a given rate through the canister.

The resistance is determined on Apparatus, MB Test Smoke, MITE4R1 in accordance with CWS Directive.*

(b) Smoke Penetration.

The ability of the canister to protect against toxic smokes is measured by a penetration test using nontoxic methylene-blue smoke. The test is conducted by forming a smoke of air-floated methylene-blue particles and drawing this smoke through a rock-wool prefilter to remove the coarse particles of methylene blue. The air stream carrying the small methylene-blue particles is then forced through the canister. A small sample of the air passing through the canister is taken from one of the canister nozzles and drawn through a paper strip holder. Simultaneously, a portion of the smokeladen air is drawn through a standard filter and then through a similar paper strip holder. Similar paper test strips are placed in the two-strip holders to collect the smoke penetrating the canister and a standard filter, respectively. Since the airflow rates through the two test strips are the same (32 l/min), a comparison of the color intensities of the strips after a short period of operation (2 min) gives the relation between the penetration of the facepiece protector canister and the standard filter.

The apparatus, operating diagram, and procedure are all described in CWS Directive 331.

(c) Rough Handling and Phosgene Test.

The object of this test is to insure that the canister has been properly filled and that the phosgene capacity of the canister is equal to that specified. The test consists of rough

*CWS Directive No. 331. Directive for Performing Methylene Blue Smoke Tests and Resistance Test on Canister (For Three-Man Facepiece Protector, E22).

handling the canister for 2 hours in accordance with a CWS Directive* and then measuring the capacity of the canister to remove phosgene from the air passing through it. The test is conducted by passing air containing 10 mg of phosgene per liter through the canister at 15 cu ft/min. The time, in minutes, that the canister prevents the passage of a detectable amount of phosgene, as determined by a suitable chemical indicator, is a measure of the life of the canister.

(3) Hose, Corrugated, Flexible.

Three 6-ft lengths of stockinette-covered, flexible, corrugated, 3/4-in. rubber hose are supplied with each protector. They carry the purified air from the air-purifier assembly to the facepieces. The construction and dimensional requirements of the hose are critical and the hose must be inspected visually and with suitable measuring instruments for compliance with the applicable drawings. Additional tests and the procedure for making them are given in a CWS specification.**

(4) Facepiece (For Three-Man Facepiece Protector, E22).

Three lightweight facepieces are attached to the end of each 6-ft length of 3/4-in. hose. These facepieces are worn over the face with a somewhat looser fit than a gas mask, since positive air pressure is blown into the facepiece by the air purifier assembly. All finished facepieces are visually examined to ascertain that each facepiece is in complete accordance with the assembly requirements.† All seams, joints, and tab attachments are inspected to ascertain that they are neat and secure, particularly the joint between the plastic eye lens and the stockinette-covered material of which they are constructed.

4. Air Locks.

An air lock is an intermediate verstibule or chamber between the outside and the inside of a shelter. Its purpose is to prevent the entrance of contaminated air into the shelter on entry or exit of personnel during attack.[33,58]

Comparative tests on existing air locks and arrangements of equipment were made by the Engineer Board at Fort Belvoir early in 1943. In this series of tests it was found that a small air lock was superior to a large air lock. The air locks were also tested in series and it was found that without the use of the airblast feature of the collective protector there is little difference between the effectiveness of one or two air locks. Tests were also conducted to determine the proper time interval for making exits from a protected room into an irritant gas-filled space without admitting the irritant. The results indicated that a 3-min interval is required to exit personnel from a sheltered area, and at this exit rate one small air lock is just as effective as two.§

*Directive for Performing Rough Handling and Phosgene Test on Canister for Three Man Facepiece Protector. CWS Directive No. 332.

**Hose, Corrugated, Flexible. CWS Tentative Spec. No. 197-54-420.

†CWS Drawing No. C5-2-665.

§Investigation Gas Proofing Equipment. Project GNS 402. Engineer Board. 30 July 1943.

In 1943 a study of air locks was authorized under Project D4.3 C to design air locks for use in all types of permanent or semipermanent gas-proofed inclosures and particularly for plotting rooms of sea-coast artillery batteries and decontamination centers. In addition, an air lock for the introduction of litter cases into decontamination centers and field hospitals were requested.

Tests undertaken as a result of this project indicate that the controlling factors in air lock construction are: (1) quantity of air available to discharge through the locks, and (2) baffling of air currents through the lock to prevent formation of eddy currents and "dead spots." It is also essential that the correct size air relief openings be used so that the maximum quantity of air will be delivered through the locks while maintaining sufficient internal pressure in the shelter.

The recommended size of the air lock is 4 by 4 by 7 ft for the vertical lock and 2½ by 2½ by 8 ft for the horizontal (litter case) lock. A two hundred cu ft of air per min discharge through a single lock is sufficient to prevent the entrance of contaminated air from the outside into the shelter if the air currents are correctly baffled. Persons entering the shelter must remain in the lock for only 1 min. If the net air discharge from the shelter is less than 200 cu ft/min, but greater than 50 cu ft/min, a double lock is required to prevent entrance of contaminated air from the outside. Persons entering pass immediately through the outer lock into the inner lock where they remain for 1 min before entering the shelter. If the net discharge from the shelter is less than 50 cu ft/min, either more collective protectors must be used or the leakage of the shelter must be reduced. If 50 cu ft/min are available for discharge through a horizontal lock for litter cases, contamination by persons entering will be negligible. If possible, however, 100 cu ft/min or greater should be the design goal.[58]

In the course of this work it was also found that there was little benefit to directing blasts of purified air over clothing worn by persons entering from atmospheres contaminated with such agents as chlorine, phosgene, and chloropicrin. An airblast will not remove persistent agents such as chloroacetophenone or the liquid vesicants. It was also noted that correct baffling of the air entering an air lock is essential to facilitate clearance of airborne contamination from the lock and to minimize entrance of contaminated air into the shelter. A knowledge of the leakage characteristics of a given shelter and the available air input to the shelter are necessary to determine the size of the air relief openings required and the number of anti-back-draft relief valves required. The relief valve shown in figure 50 has been found satisfactory.

The recommendations contained in MITMR 46, Air Lock, are incorporated in part XVI, chapter 2, Engineering Manual, Military Construction Protective Structures, Collective Protection Against Chemical and Biological Attack, September 1948.*

*ETF 625-30.

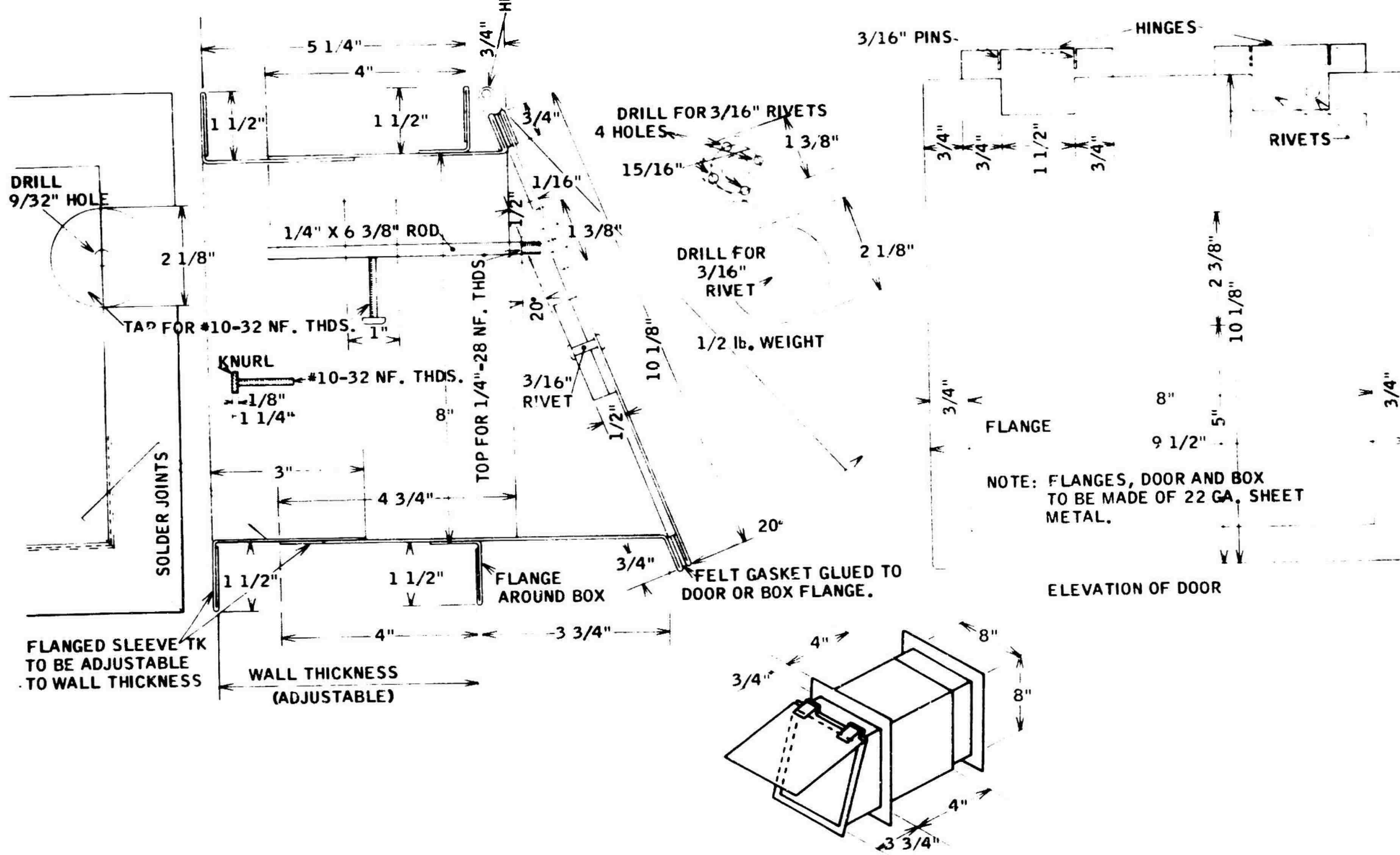

Figure 50. Pressure Release Valve Layout of CWS Gasproof Equipment for Testing

IV. DESIGN CHARACTERISTICS

A. Fixed Installation Protectors (Protector, Collective, M1, M1A1, and M1A2).

No specific military requirement for this item was ever stated as such. The correspondence standardizing these collective protectors carried the implication that there was a military requirement by the Coast Artillery and other services.*

No approved military characteristics were written for this type of collective protector.

The M1 Collective Protector was described in the historical section which included a photograph.

For large installations requiring multiple units, it was impracticable to order M1 Collective Protectors since they included components that were unnecessary. The practice, therefore, arose of ordering parts by drawing numbers and assembling the requisite items for the particular installation. Such nonstandard assemblies came to be known as the M1A1 Collective Protector, although there was no standardized item of such a description. Modifications were made from time to time and the item was ordered under a special authorization.[59,60]

This method of procurement suited actual needs so much better than the one formerly in use for ordering M1 Collective Protectors that this latter model fell into disuse. In January 1944, the latest design of the M1A1 Collective Protector was standardized and the M1 Collective Protector, was redesignated as a limited standard.

The M1A2 Collective Protector was designed for either right-hand or left-hand installation. It consisted essentially of an electric-drive motor, a bypass, and a canister. Assembled, this unit required a base 21-3/4 in by 49-1/2 in. The electric-powered blower was mounted at one end of this base. At the opposite end of the base was located the M1 Canister which was held in a vertical position by an appropriate support. The connection between the blower and the canister was made up of a "tee" pipe section and an elbow. In the "tee" section was located a diaphragm valve by means of which air coming from the blower could be directed to the canister through the elbow connection or to the remaining opening of the "tee" section. The last-mentioned opening was directed upward between the blower and the canister, and leading from this was the bypass pipe which extended upward and by means of an elbow and nipple connected with the discharge pipe at the top of the canister. In this discharge pipe, between the canister and the point of connection with the bypass was a second valve. By means of this valve and the one in the "tee" section at the base of the canister, incoming air might be directed either through the bypass or through the canister, as circumstances required. The unit was capable of delivering 200 cu ft/min of purified air.[60]

A number of tests have been made on the fixed installation-type of collective protector. These tests were mentioned in the historical section.

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*Chemical Warfare Service, Letter, 354.2/10, 15 July 1932 to OC CWS. Adoption of Protector, Collective, M1, to AG and indorsements 1st thru 6th thereon.

Some M1 Collective Protectors from Panama were tested after their return from service. These canisters were filled with Type A charcoal and had carbon impregnated paper smoke filters. The filters showed a very poor protection against smokes probably because they had been "broken down" by oil screening smokes and the moist Type A charcoal had poor life against some gases. It was recommended that all collective protector tubes be filled with Type ASC charcoal and wrapped with asbestos-bearing or asbestos-impregnated paper.[61]

B. Large Field Collective Protector, M2, M2A1, and M2A2.

1. Military Requirement.

A military requirement was implied by correspondence approving a set of military characteristics for a large field collective protector with the concurrence of the representatives of interested arms and services in 1935.

2. Latest Approved Military Characteristics.

(a) It should be light in weight. If possible, the total weight should be kept below 400 pounds.

(b) It should have a capacity of 200 cu ft/min of purified air.

(c) It should be designed so that inexperienced personnel will be able to place the unit in operation in a minimum length of time by following simple instructions.

(d) The unit and the component parts should be so designed that it can be handled by men without the aid of a crane lift of any kind.

(e) The unit should be capable of being broken down into the smallest packages practicable to facilitate handling and shipping.

(f) Provision should be made for both interior and exterior installations.

(g) It should be designed so that the relative invulnerability of component parts of the assembly is approximately the same.

(h) The unit should be as small as practicable, so that it can be installed in the minimum space, and also so that it will not take up excessive shipping and storage space.

(i) It should be gasoline-engine operated.

(j) The canister should have a positive seal with "Not to be opened until in presence of gas" stamped on it.

(k) If possible, provision should be made for hand operations.[26,62]

3. Large Field Collective Protectors.

The M2 and M2A1 protectors are described in the historical section. Figure 51 shows a view of this protector. The M2A1 Collective Protector was the same as the M2 except that it was powered by a gasoline engine.

The two units were known as the M1 and M1A1 Field Collective Protectors. However, on 2 May 1942, the designations were changed to M2 and M2A1 Collective Protectors, respectively.[63]

To correct the defects of the M2 (E10R1) Collective Protector further development work resulted in the E10R2 Collective Protector which was later designated as the M2A2 Collective Protector.[64]

The basic difference between the M2A2 Collective Protector and its predecessors was in the arrangement of parts which were the same for both. This unit had a total weight of 615 pounds, completely assembled. It was 5 ft, 4 in long, 2 ft, 1 in. wide, and 2 ft, 5 in. high with a total cubic displacement of 27 cu ft as compared with 38 cu ft in the M2 and M2A1 units. The E10R2 unit was mounted on a rectangular frame 5 ft, 7 in. long and 2 ft, 1 in. wide. This frame had carry-handles on each end and along each side. At one end of this frame there was located an enclosed sheet-metal compartment equipped for storage of spare parts and tools. On the top surface of this compartment there was mounted a four-cycle, air-cooled, one-horsepower, gasoline engine. This engine was connected by direct drive to a No. 9 air blower which was also mounted on the top surface of the compartment. The remainder of the frame was occupied by the canister which was held in a horizontal position by two adjustable flat steel straps. These straps were so designated that either the M1 Collective Protector Canister, which was cylindrical in form, or the rectangular MITE11 canister could be used. The discharge pipe of the blower connects directly to the intake orifice of the canister. To the outlet orifice of the canister there was connected a 4-in. diameter flexible metal hose 20 ft long which was used to deliver purified air to the gasproof chamber served by this unit.[63]

The M2A2 Collective Protector M2A2 was adopted as a standard item on 3 February 1944. At the same time the M2 and M2A1 Collective Protectors were redesignated substitute standard items.[63 65] In February 1945, the M2 and M2A1 Collective Protectors were redesignated as limited standard items.[66,67]

4. Tests of Large Field Collective Protector.

A number of tests were conducted on the large field collective protector before1940. These tests were reported in the historical section.

In 1944 a number of field tests were conducted on the M2 Collective Protector to determine its resistance to rough handling, gas protection, and to answer a number of questions asked by people in the field. It was found that the protector had good resistance to rough handling. It also provided good protection against field concentration of SO_2, CN, FS, and Cl_2, but only partial protection against CC because the charcoal used was the Type AS instead of Type ASC.[68]

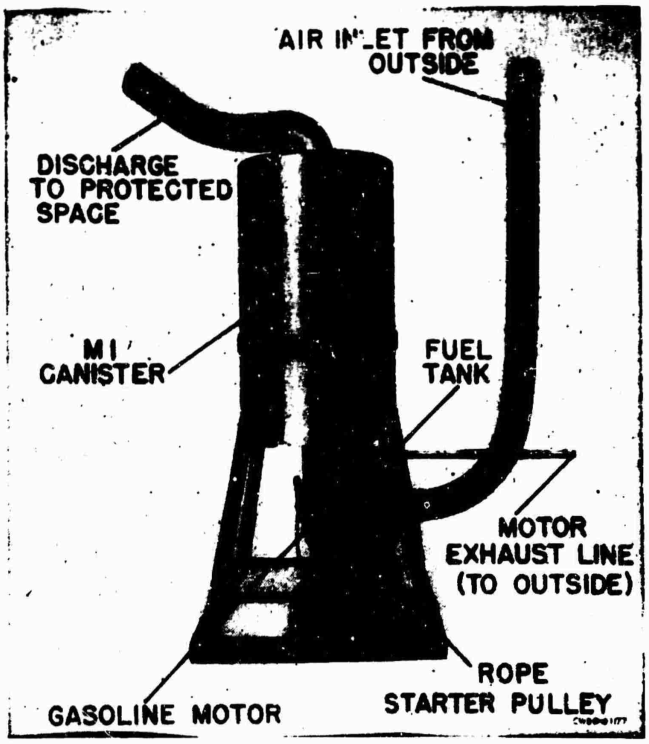

Figure 51. Collective Protector M2

C. Canister, Collective Protector, M1

1. Military Requirement.

There was a military requirement for a collective protector canister to be used as a replacement for collective protectors set up in military installations.[69]

2. Military Characteristics.

None written.

3. Description of Various Models.

The development of this item was completed previous to the year 1940. Originally it was included in the Army Chemical Corps Book of Standards as the M1 Collective Protector Canister meaning the canister for the M1 Collective Protector. However, with the development and standardization of the M2 Collective Protector, it was felt that the name was confusing since the same canister was used for both the M1 and M2 Collective Protectors. The proposal was therefore made that the name be changed to Canister for Collective Protector, M1 or M2.[69] However, with the development of the M1A1, M2A1, and others the situation again became confusing and the original designation of Canister, Collective Protector, M1, was again adopted.[70]

D. Further Development of the Large Field Collective Protector.

1. Military Requirement.

There was a military requirement for a large field collective protector supplying more air and lighter in weight than the M2, M2A1, or M2A2 Collective Protectors for use in field shelters, field hospitals, dugouts, mobile machine shops, laboratories, and office trailers, and on trucks and other types of trailers.[71]

2. Military Characteristics.

These items were to have the following characteristics:

(a) The protector should be light in weight. If possible, the total weight should be kept below 400 pounds.

(b) It should have a capacity of 275-300 cu ft/min of purified air.

(c) It should be capable of being driven by gasoline engine and also by an electric motor.

(d) It should be as small as practicable so that it can be installed in the minimum space, and also so that it will not take up excess shipping and storage space.

(e) It should be designed so that inexperienced personnel will be able to place the unit in operation in a minimum length of time by following simple instruction.

(f) The unit should be capable of being dismantled into one- or two-man loads to facilitate handling and shipping.

(g) Provision should be made for both interior and exterior installation.

(h) In addition to its use as a field collective protector, the unit should be capable of being used to protect personnel in mobile machine shops, laboratories, office trailers, etc.

(i) It should be designed so that the relative invulnerability of component parts of the assembly is approximately the same.

(j) The canister should have a positive seal with "Not to be opened until presence of gas" stamped on it.

(k) The canister should be capable of purifying 275-300 cu ft/min of air, and it should offer protection against gas and smoke equivalent to that afforded by the standard-service gas-mask canister.[71]

3. Description of Various Models.

a. MITE9 Field Collective Protector Canister.

The canister for the MITE9 Field Collective Protector consisted essentially of two square, axial-flow smoke filters and charcoal sections in parallel. These two sections were arranged together, with the plane of the beds horizontal, and air entering the chamber between them. Air passing upwards and downwards through the air purifier sections as in the MITE8 Canister (Tank Protector), first encountered the straight-pleated smoke filter (figure 52), then the 21.5-in. square charcoal beds. The purified air from both air filter sections was combined by plenum chambers and manifolds into one effluent airstream. A sketch of the canister is shown in figure 53.

This canister could purify 300 cu ft of air per min for 37 min when the air contained 10 mg/l of phosgene.

b. MITE9R1 Field Collective Protector Canister.

The MITE9R1 canister differed from the MITE9 model in that the baffles of the charcoal bed were made part of the spacers and the charcoal layer was supported by a bolt through its center (figure 54). Figures 55 and 56 show views of aluminum casting for this protector.[42]

c. MITE9R2 Field Collective Protector Canister.

The canister of the MITE9R2 Field Collective Protector was 26 in. square inside. All other features were the same as the MITE9R1 canister.[42]

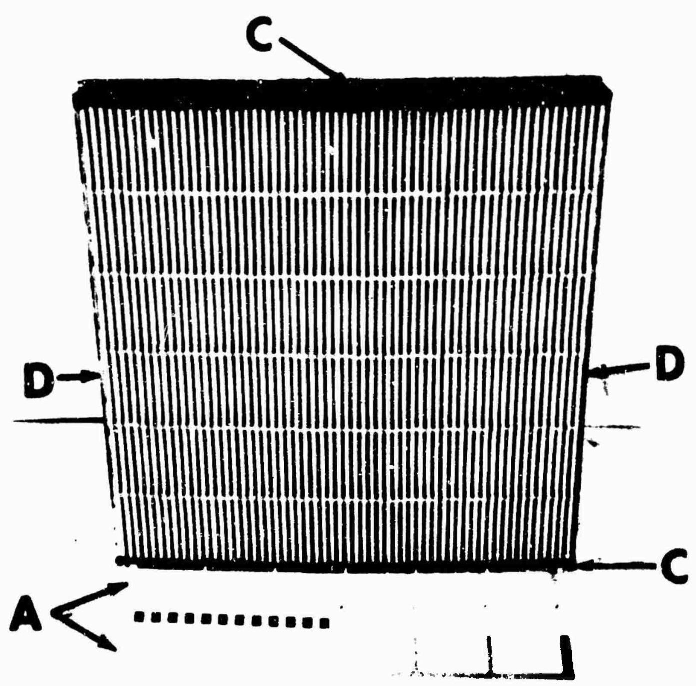

Figure 52. Assembled Square Filter

A. Carboard combs below the filter; B. assembled filter with the combs in place; C. dark colored cemented edges; and D. solid carboard pieces on each side of the filter.

d. MITE10 Collective Protector Canister.

The MITE10 Collective Protector Canister consisted of three cylindrical canisters arranged in parallel. Each axial-flow canister was 20-3/8 in. in diameter and contained a filter section with 14, 4-1/8 in. diameter, shell-type filters mounted in parallel in a suitable frame. The charcoai bed was to be 2-1/4 in. thick and supported by a bolt through the center. Two 60° spiders served as the inlet and exhaust manifolds. Figures 56 and 57 show this unit and its parts.[42]

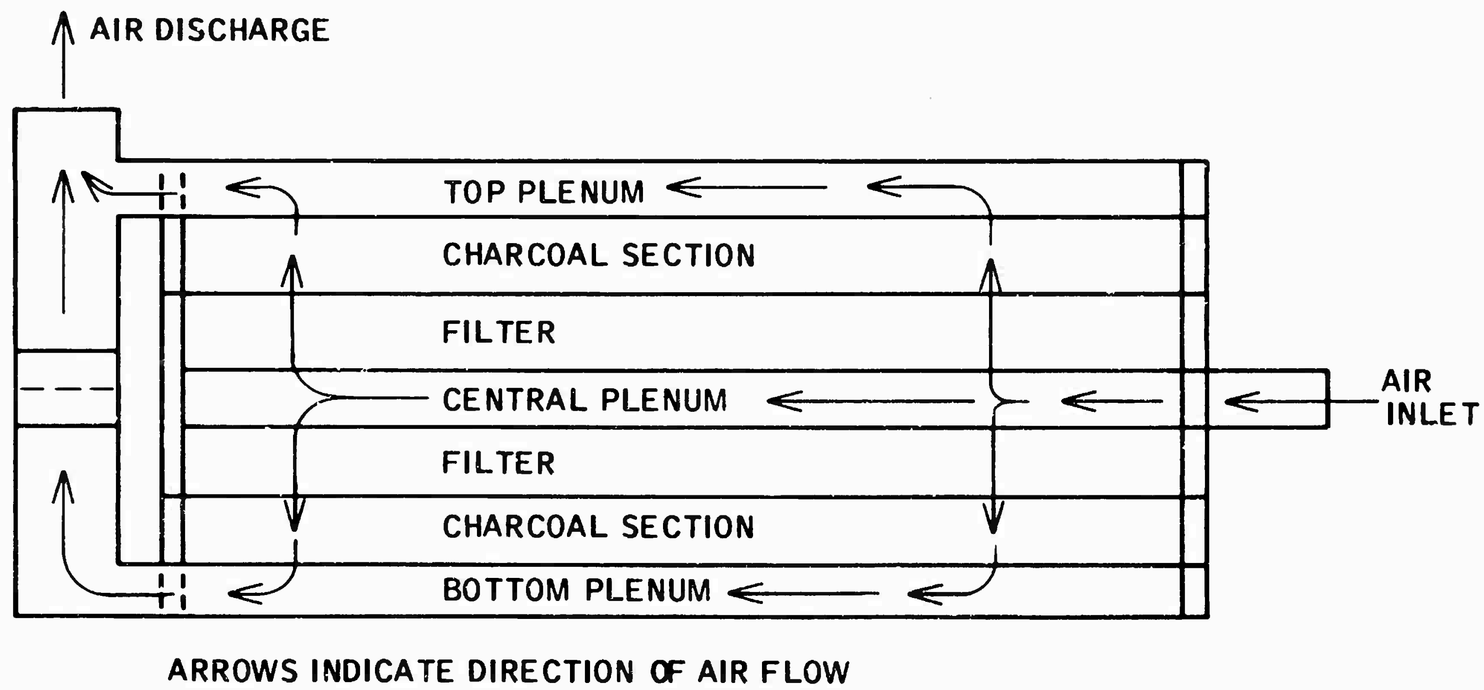

Figure 53. Sketch of Canister of MITE9 Field Collective Protector

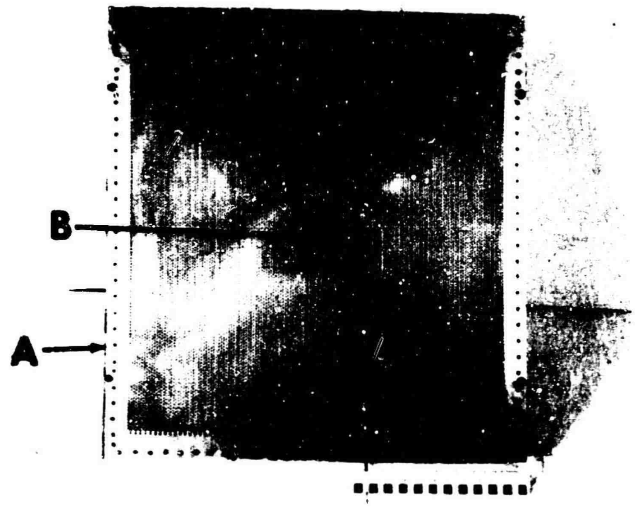

Figure 54. MITE9R2 Field Collective Protector Charcoal Section

A. Aluminum perforated screen with the baffle incorporated; and B. bolt and washer in the middle of the screen to give added support to the charcoal bed.

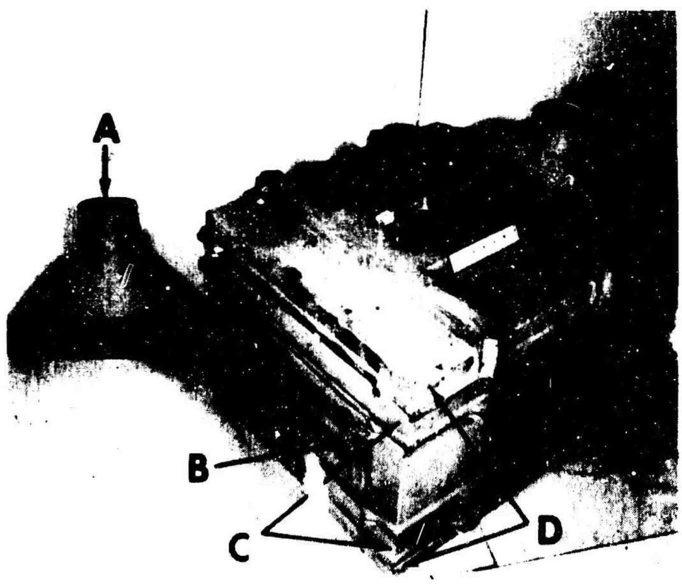

Figure 55. MITE9 Field Collective Protector Canister Casings

A. Influent-air manifold; B. inlet-air manifold and filter holder; C. charcoal sections; and D. effluent-air manifolds.

Figure 56. Effluent Air Side of MITE9 Field Collective Protector Canister Castings

e. Blower and Gasoline Engine.

Since no suitable blower could be found on the market, a special blower was designed for these collective protectors. Calculations showed that the blower would have to deliver 300 cu ft of air per min against a static pressure of about 8 in. of water. The development of a spiral aluminum housing and a shrouded impeller with 15°, forward-slanting blades, which satisfied these conditions, was therefore undertaken.

The gasoline engine for the new collective protector was a Briggs and Stratton Type NP, 1-1/2-horsepower model with a speed of 3400 rpm.[42]

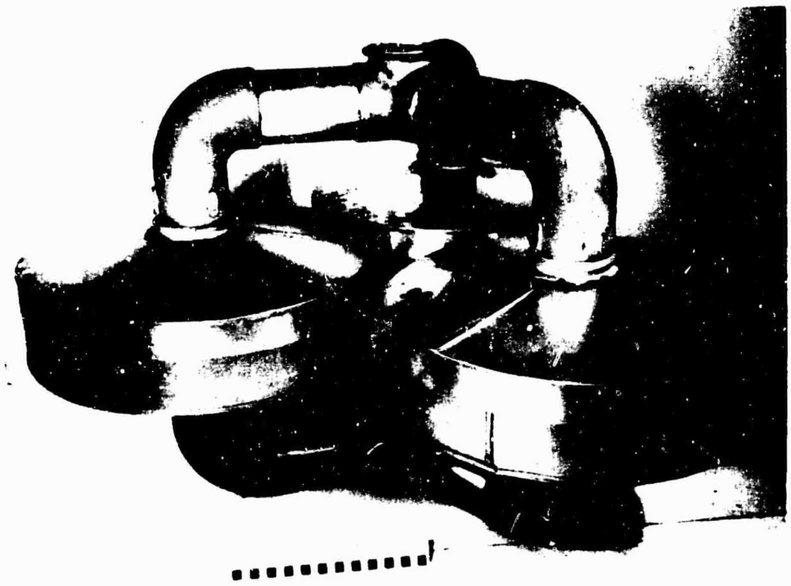

Figure 57. MITE10 Field Collective Protector Canisters

4. Tests.

a. General.

The MITE9 design was tested only in wooden mockups. The aluminum castings were never put together and tested. The MITE10 Collective Protector was never assembled and tested.

b. Gas Life.

The MITE9R1 Collective Protector Canister had a phosgene gas adsorption life of 36 min at an air flow of 300 cu ft/min and a gas concentration of 10 mg/l. The MITE9R2 Collective Protector Canister had a gas life of 56 min when tested under the same conditions.

c. Rough Handling.

The MITE9R1 Collective Protector Canister did not rough handle well on edge. Further work was required to strengthen the charcoal bed.

E. Small Field Collective Protector

1. Military Requirement.

A military requirement for the small field collective protector was established by the correspondence approving a set of military characteristics with the concurrence of the representatives of the interested arms and services.

2. Military Characteristics.

(a) The small field collective protector will be of a size capable of installation and operation in a narrow trench.

(b) It must be capable of breakdown into parts for transportation by men, no part should weigh more than 75 pounds and preferably no more than 50 pounds.

(c) It will be equipped for operation by means of a small gasoline-engine-drive blower, and in addition must be capable of operation by hand in emergencies. For special purpose only, and upon definite statement of requirements, it will be equipped with a small electric motor of appropriate voltage in place of the gasoline motor.

(d) It will be equipped with flexible tubing through which to draw and deliver the air. This tubing will be extensible by additions of 20-ft lengths.

(e) It shall be rugged enough to withstand such rough handling as will occur in breakdown and transportation by man or truck.

(f) The type of protection will be equal to that afforded by the standard service gas-mask canister. Fifty cu ft of purified air per min will be provided.

No collective protector was ever standardized as fulfilling the above listed military requirements. Most of the work leading up to the development of the collective protector for trailer installation was done in an attempt to develop a satisfactory small field collective protector. This work is discussed in the historical section and the final model, the M3 Collective Protector, was described in section F.

F. Collective Protector for Trailer Installation.

1. Military Requirement.

In military requirements submitted by the Chief, Field Artillery, and approved by the Adjutant General for sound- and flash-ranging trailers, there was included a requirement

that a gas-eliminating canister through which air for ventilation was drawn into the body be supplied.* A formal military requirement was set by the Adjutant General in the process of standardizing the M3 Collective Protector.[23,72]

2. Military Characteristics.

(a) It shall be of a size capable of installation and operation in mobile machine shops, laboratories, office trailers, etc.

(b) It shall be equipped for operation by means of a small electric-motor-drive blower.

(c) It shall be equipped with flexible tubing through which to deliver the air.

(d) It shall be rugged enough to withstand travel over rough terrain.

(e) The type of protection will be equal to that afforded by the standard service gas-mask canister.

(f) It shall provide 50 cu ft/min of purified air.[23]

The development of the M3 Collective Protector is described in the historical section.

3. Tests of M3 Collective Protectors.

The M3 Collective Protector was tested by the Chemical Warfare Board and was found to meet all military requirements. However, the protection against CC gas was inadequate because the canister of the protector was filled with Type AS charcoal.

The 50 cu ft of purified air per min supplied by this protector was insufficient to protect the mobile machine shops. Gas entered through leaks in the trailer body while the protector was in operation.[73] The problem of protection against CC was solved when the collective protector canister was filled with Type ASC charcoal. Tests of M3 Collective Protectors so filled gave good protection against CC gas.[74]

A test was made to determine how much air was required to protect a mobile machine shop from gas penetration since the M3 Collective Protector delivering 50 cu ft/min provided insufficient air to maintain a positive pressure within the mobile machine shop.

An M2 Collective Protector was set up outside a mobile shop and connected to it with flexible hose. To keep gas from entering the protected area, 280 cu ft/min airflow was required. When the obvious points of leakage were sealed, only 90 cu ft of air per min was necessary to insure protection. However, the latter figure had to be raised to 110-125 cu ft of

*Chemical Warfare Service, Letter, 451.2/133. 27 October 1934. Holabird Quartermaster Report to OC CWS. Subject: Trailer - Loud Ranging.

air to prevent gas entry after the truck was driven for 100 miles over unpaved roads. The conclusion was that the M3 Collective Protector did not provide sufficient air to adequately protect a mobile machine shop.[75]

The canister of the M3 Collective Protector (known as the Canister, Collective Protector, M2, although it was never standardized) was originally made with a filter of carbon-impregnated filter material. When the filter material was changed to a lower resistance asbestos-bearing paper, the pressure drop of the assembly was decreased considerably with a consequent increase in the flow delivered by the blower. This increased flow caused a dangerous decrease in the gas life of the canister. Tests were conducted which showed that placing a 1-5/8 in. orifice plate in the canister discharge would remedy this situation.[41]

G. Civilian Collective Protector.

1. Military Requirement.

The military requirement for this item was implied in the standardization correspondence.[76] The project specification stated the need for a collective protector for civilian use.*

2. Military Characteristics.

The military characteristics of this protector, outlined in the project specification, were:

(a) Protect against all toxic smokes and gases.

(b) Deliver a sufficiently large volume of air to enable habitation of civilian bombproof shelters.

Technical characteristics were developed to implement the military characteristics.

(a) Be of such design as to be easily installed in an air-raid shelter large enough to comfortably hold 40 persons.

(b) Supply fresh, purified air to the shelter at a rate of 200 cu ft/min.

(c) Be operated by electricity but be capable of continuous hand operation in case of power failure.

(d) Be rugged in construction and capable of manufacture in large quantities at reasonable cost.

(e) Be simple to operate.

(f) Withstand rough handling of the type which would be received in transit, installation, and use.

---

*Project D4.1-10 Specification. 16 October 1942.

(g) Require a minimum amount of critical material and machinery.*

3. Description of Preliminary Models of Civilian Collective Protector.

a. Civilian Collective Protector MITE1.

The MITE1 Civilian Collective Protector is shown in figure 58. This model consisted of four separate chambers. The uppermost was an intake plenum designed to be connected to the outside atmosphere by means of an 8-in. sheet iron pipe.

The next lower section consisted of a framework over which filter paper was wrapped (see figure 59). The total filter consisted of 3 layers of impregnated alpha web of approximately 33 sq ft in area. This number of layers was used for experimental purposes only. The filter section was difficult to fill without tearing the paper and to make airtight.

The next lower section consisted of the four trays of charcoal 1-1/2-in. thick arranged vertically between spaces and enclosed on both sides with perforated metal. These trays were equipped with spring followers to keep the charcoal under compression at all times regardless of settling which might take place. Air coming from the filter was split four ways and passed through these trays in parallel.

The bottom section housed the fan, motor, and outlet pipe. Although the fan maintained the entire unit under slight vacuum preventing leaks outward through the walls of the unit, a large number of rubber gaskets was required to prevent internal leakage.

The unit was designed to have a bypass from the inlet plenum to the fan and a second from the outlet of the filter section to the fan, both bypassing the charcoal beds. These bypasses were never installed due to change in design of the collective protector and termination of work on this model.

b. Collective Protector MITE2.

The MITE2 Collective Protector is shown in figure 60 and a view of the interior is shown in figure 61. This design differed radically from the model E1 in that a single canister section was used for both the smoke filter and the gas adsorbent; rock wool was used as the smoke filter.

The constructional features of this unit are worthy of note. The entire canister was of arc-welded construction, all separating screens and metal sheets were arc-welded with a continuous bead requiring about 120 ft of continuous weld. Air was drawn into the top of the unit and divided into two paths entering the two large slits shown in figure 61. Each air stream again divided and flowed first through the rock wool filter and then through a bed of charcoal–soda lime mixture. At the bottom of the canister a motor and blower were installed. The charcoal–soda lime mixture was held between two perforated sheet metal screens which were spaced 1-1/2 in. apart and were braced with 1/4-in. mesh iron screen and one of the

*Project D4.1-10 Specification. 16 October 1942.

charcoal frames. The total area of the filter material was approximately 13.5 sq ft and 3 layers of rock wool were used as a filter. This unit was gasketed with rubber sheeting; however, this type of gasket was not contemplated for ultimate use in collective protectors.

Figure 58. Civilian Collective Protector MITE1

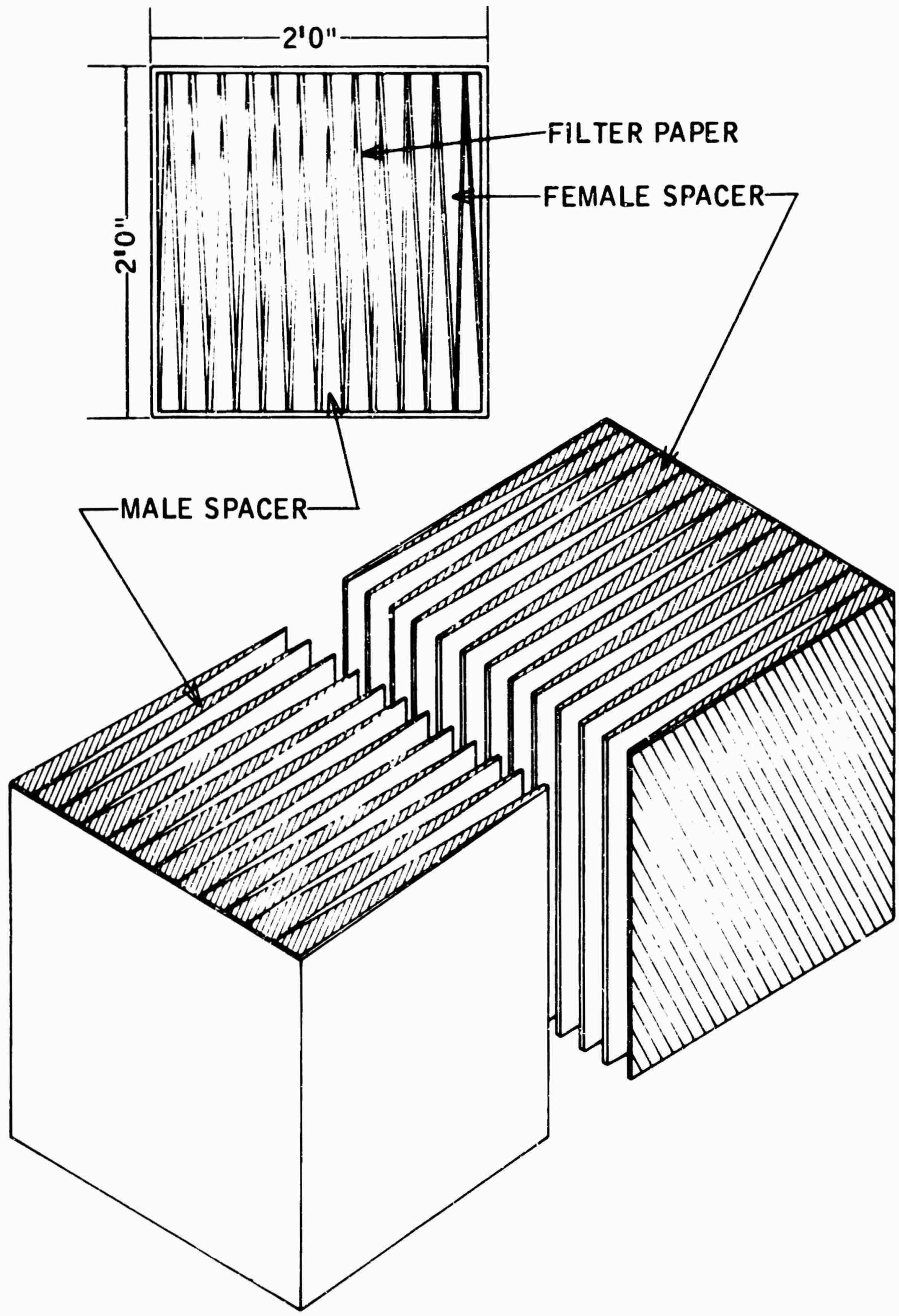

Figure 59. Filter Paper Holder Collective Protector MITE1

Figure 60. Civilian Collective Protector MITE2

c. Collective Protector MITE2R1.

The MITE2R1 Collective Protector is shown in figure 62 and its internal construction is shown in figure 63. This unit differed from model E2 in that the canister was inverted; the contaminated air was drawn in from the bottom and discharged from the top, a feature which was incorporated to allow the construction of a unit having both motor and blower mounted on top. Another difference was the use of grooved sides to allow the internal screens to be inserted and tack welded into place, thus eliminating the need for continuous arc

welding at these points and reducing the amount of such welding to approximately 32 ft for the entire unit. The principle of operation, however, was the same as that for the E2 model. Air entered the bottom, divided into four streams, and passed first through rock wool and then through charcoal–soda lime mixture.

Figure 61. Civilian Collective Protector MITE2
(inside view)

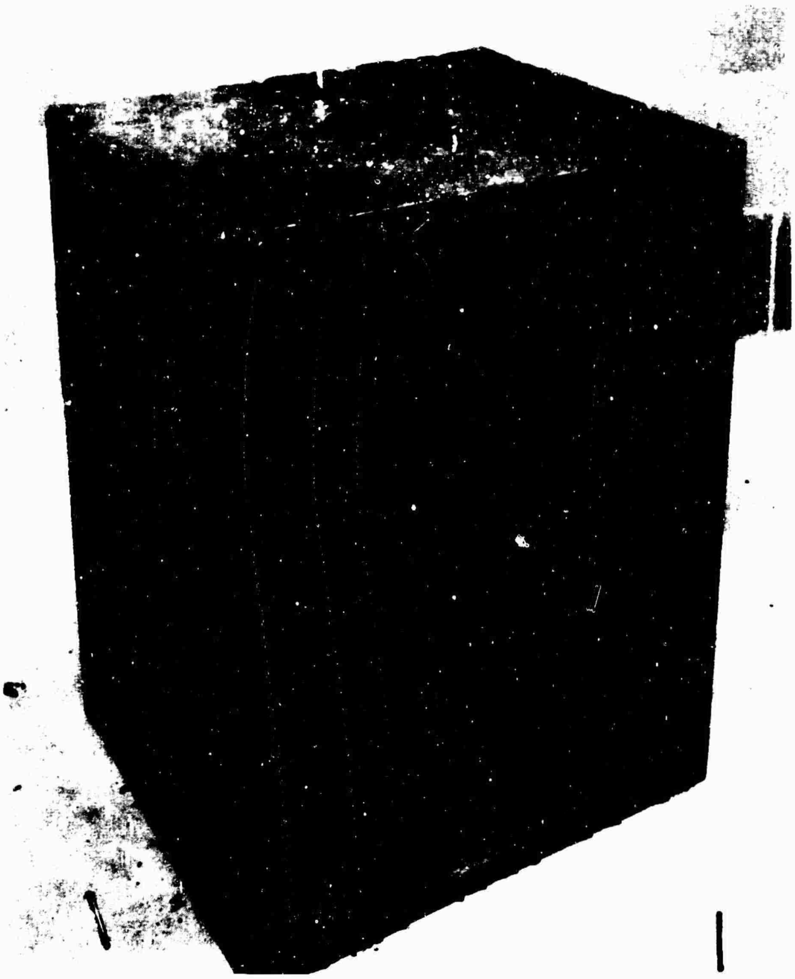

Figure 62. Civilian Collective Protector MITE2R1
(outside)

This unit was equipped with a pyramidal cover ending in a 6-in. round pipe adapter. A pipe was led from this to a Sturtevant 00 blower, and the outlet of the blower was connected to a discharge pipe and an orifice for measuring the flow. The shaft of the blower was attached to a hand crank by means of a chain-connected, speed-increasing mechanism.

Due to the flanges at the end of the rock wool compartments, shown in figure 63, this unit was difficult to fill, and accurate flow, pressure drop, and smoke penetration tests were impossible. However, preliminary gas tests with chlorine and carbon tetrachloride were made with this unit.

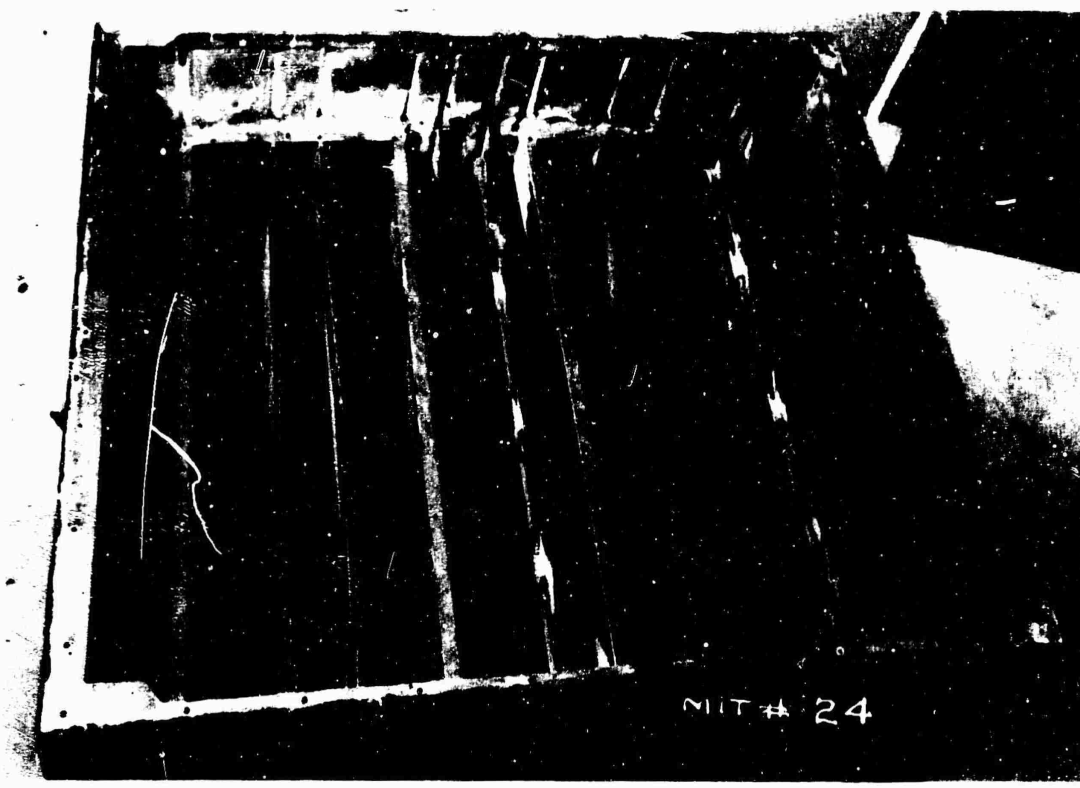

Figure 63. Civilian Collective Protector MITE2R1
(inside view)

d. Collective Protector MITE2R2.

Following the basic design for model MITE2R1, the Carrier Corporation and the Trane Company were asked to build and submit five complete units each, in order that the design might be thoroughly tested. Other than the actual principle of operation, the two companies were given a free hand in adapting the basic design to commercial production. The fan, bypass, speed increase, etc., were worked out as each company saw fit.

Model E2R2 was submitted by the Carrier Corporation. No photographs were taken or tests made of this unit because of faulty construction. The unit was returned to the company.

e. Collective Protector MITE2R3.

The first unit received from the Trane Company was designated as MITE2R3 and is shown in figures 64 and 65. This unit had an internal construction similar to the E2R1 model with the exception that perforated sheet iron rather than brass, braced with 1/4- by 3/8-in. steel bars, was used for the charcoal frames.

A spun glass prefilter was installed at the bottom of the unit for the removal of dust and dirt, and a felt filter to remove charcoal fines was used in the upper portion of the unit. The headbox was equipped with a forward curved-blade, squirrel-cage blower, which was connected to a 1/4-hp motor. The motor was of the gear-head type, which could be turned by hand crank connected to the low-speed shaft. The gear ratio (speed-increase ratio) was 87:1, allowing an operating-fan speed of 3450 rpm at a handcrank speed of 40 rpm.

f. Collective Protector MITE2R4.

This unit differed from the E2R3 only in that the prefilter was situated horizontally rather than on an incline; the inlet was rectangular instead of round and was on the opposite side of the unit from the handcrank. A round-to-rectangular adapter was supplied with the unit for connection to an 8-in. inlet pipe. Carrying and anchoring lugs were walded to the canister. The method of carrying is illustrated in figure 66.

g. Collective Protector MITE2R5.

The MITE2R5 Collective Protector is shown in figure 67 in comparison with a model MITE2R4. The only difference was the MITE2R5 was stripped of motor, fan, and headbox. It was designed for multiple unit operation.

Figure 68 shows an experimental installation of five units capable of delivering 1250 cu ft/min, 250 cu ft/min being drawn through each canister.

h. Collective Protector MITE2R6.

The MITE2R6 Collective Protector is shown complete in figure 69 and with the top cover removed in figure 70. This unit differed from the E2R4 unit in that the two filter sections were assembled as complete units, separate from the body of the canister, as shown in figure 71. The cover housed these two filter sections and all bypass mechanism. The fan used was a 7-in. radial blower having flat rather than curved blades. The headbox of this unit was designed to fit a vertical air distribution header which could be made an integral part of the unit as shown in figure 72.

Chemical tests indicated no difference in protection between this unit and the MITE2R4. However, it was bulkier and more difficult to fill and assemble, and since it was later decided that there was no need for a bypass, there was no necessity for the bulky housing.

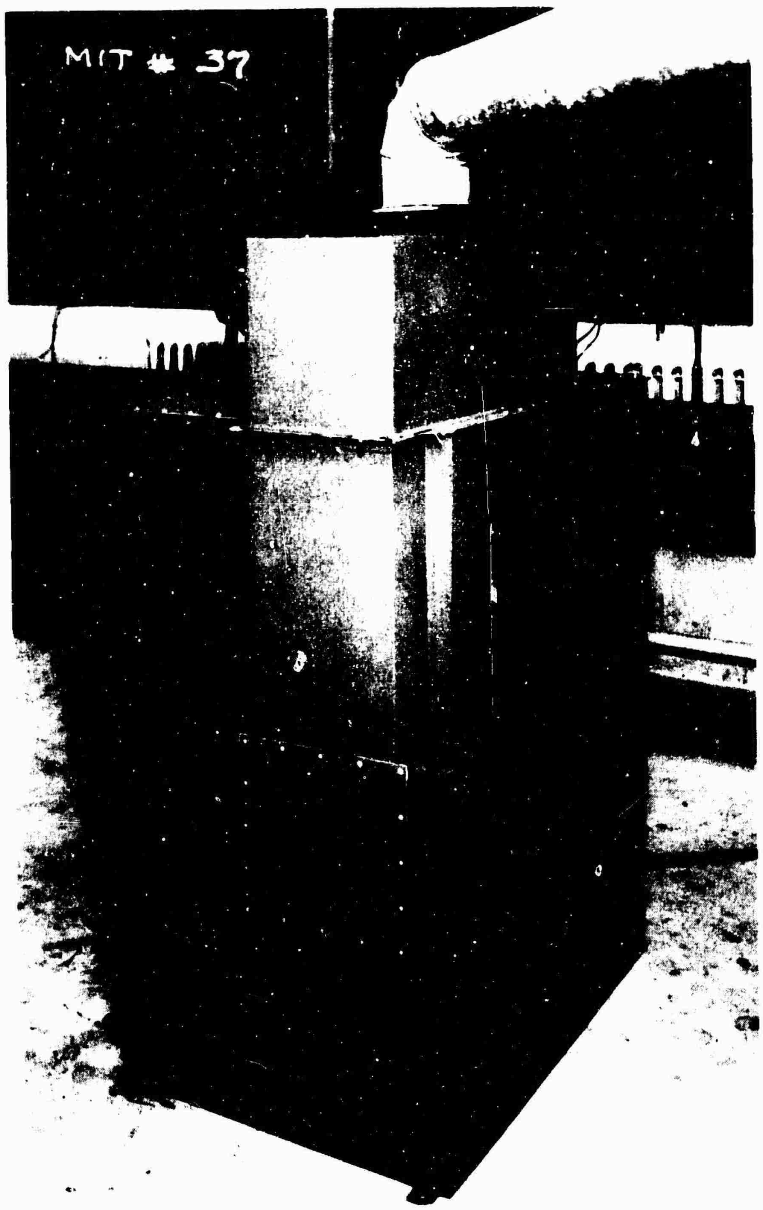

Figure 64. Civilian Collective Protector Model MITE2R3
(rear view)

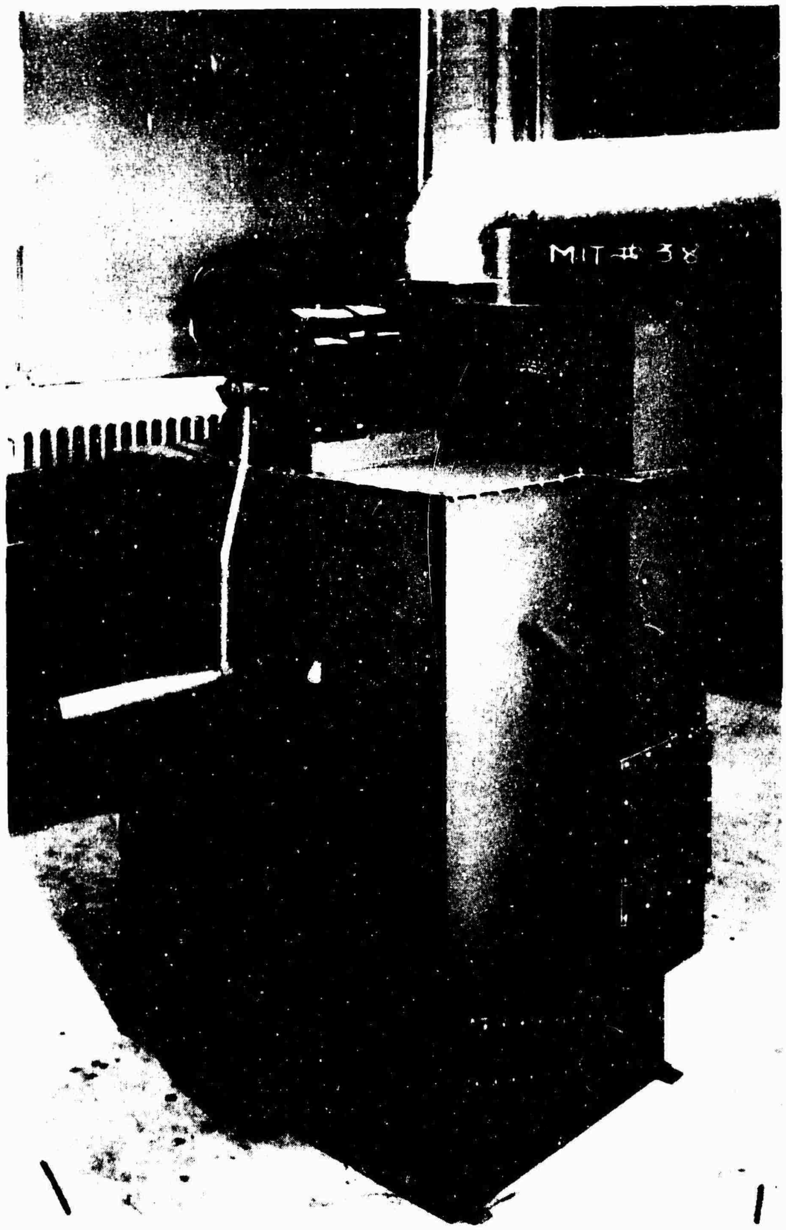

Figure 65. Civilian Collective Protector, Model MITE2R3
(front view)

Figure 66. Civilian Collective Protector, MITE2R4

i. Collective Protector MITE2R7.

The number for this unit was reserved for a multiple unit based on the MITE2R6. Drawings only were made up.

j. Collective Protector MITE2R8.

Model MITE2R8 was constructed from the canister of an MITE2R4 unit and a 7-in. radial-type blower. Engineering tests were run and it was then dismantled in order to construct one of the later models.

Engineering tests on models MITE2R4 and MITE2R6 indicated that the 7-in. radial-type fan used on MITE2R6 was a superior blower to the 5-in. forward-curved-type fan used on the MITE2R4.

Figure 67. Civilian Collective Protector Units, E2R4 and E2R5

Due to simpler construction, lighter weight, less bulky appearance, and easier handling and filling, the model MITE2R4 was chosen as the preferable canister.

k. Collective Protector MITE2R9.

This unit was the same as the MITE2R4 except for the removal of the bypass (see figure 73).

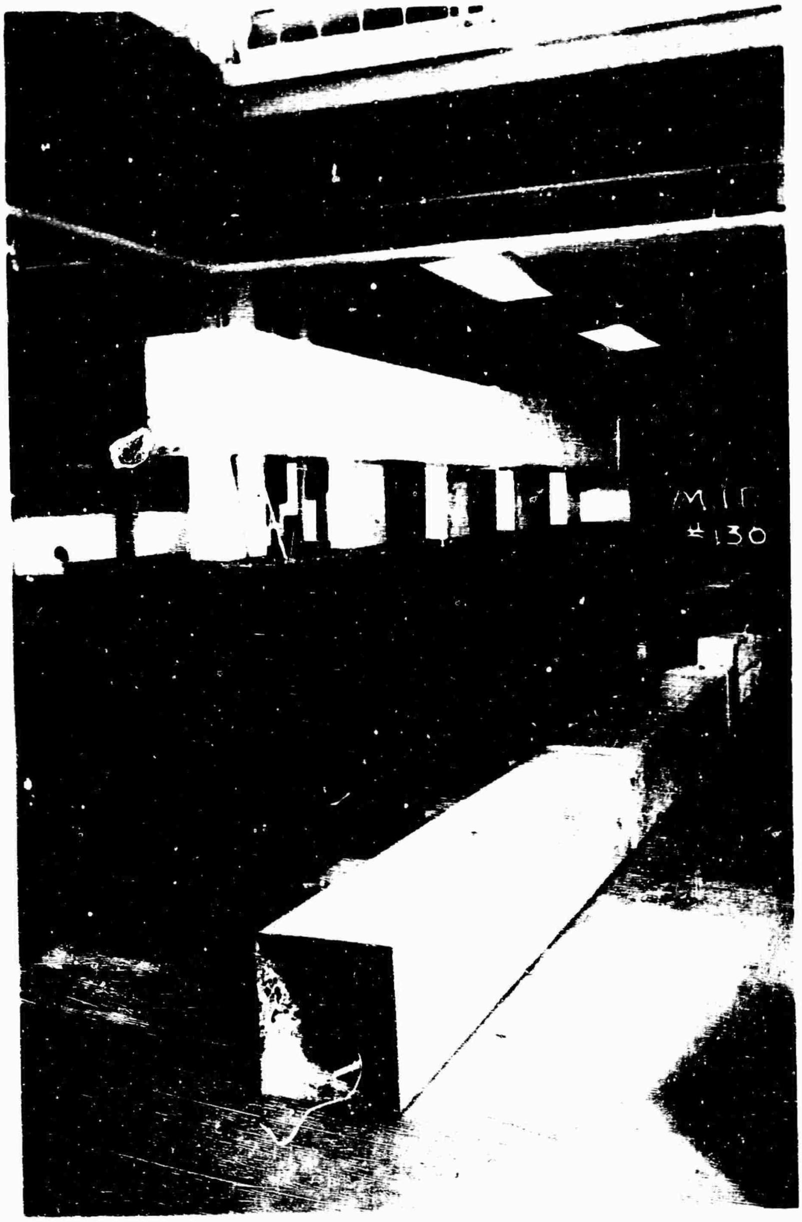

Figure 68. Installation of 5 Component Multiple Unit Civilian Collective Protectors MITE2R5

Figure 69. Civilian Collective Protector, MITE2R6

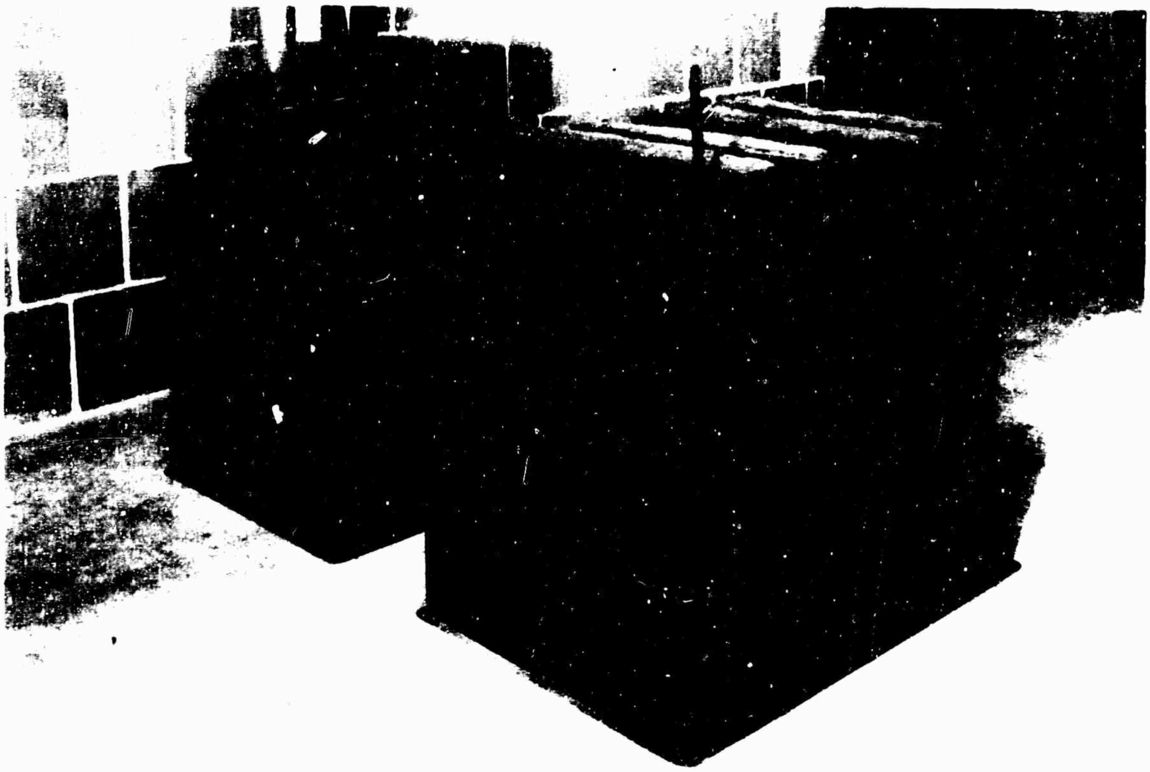

Figure 70. Civilian Collective Protector, MITE2R6

l. Collective Protector MITE2R10.

This unit is shown diagramatically in figures 74, 75, and 76. The MITE2R10 design was based on the MITE2R4 with the bypass and damper removed. A new top plate and headbox were constructed and a 7-in. radial-type fan was installed. A distribution header similar to that used in the MITE2R6 was designed for connection to the headbox. This header had three air-distributing grills which deliver the air at a height of approximately 7 ft from the floor. It was also supplied with a damper for the airblast operation, an adapter for airblast connection, and a flow indicator.

The weight of this complete unit was estimated to be about 450 to 500 lb. It was capable of being shipped in a single crate of approximately 55-cu ft capacity.

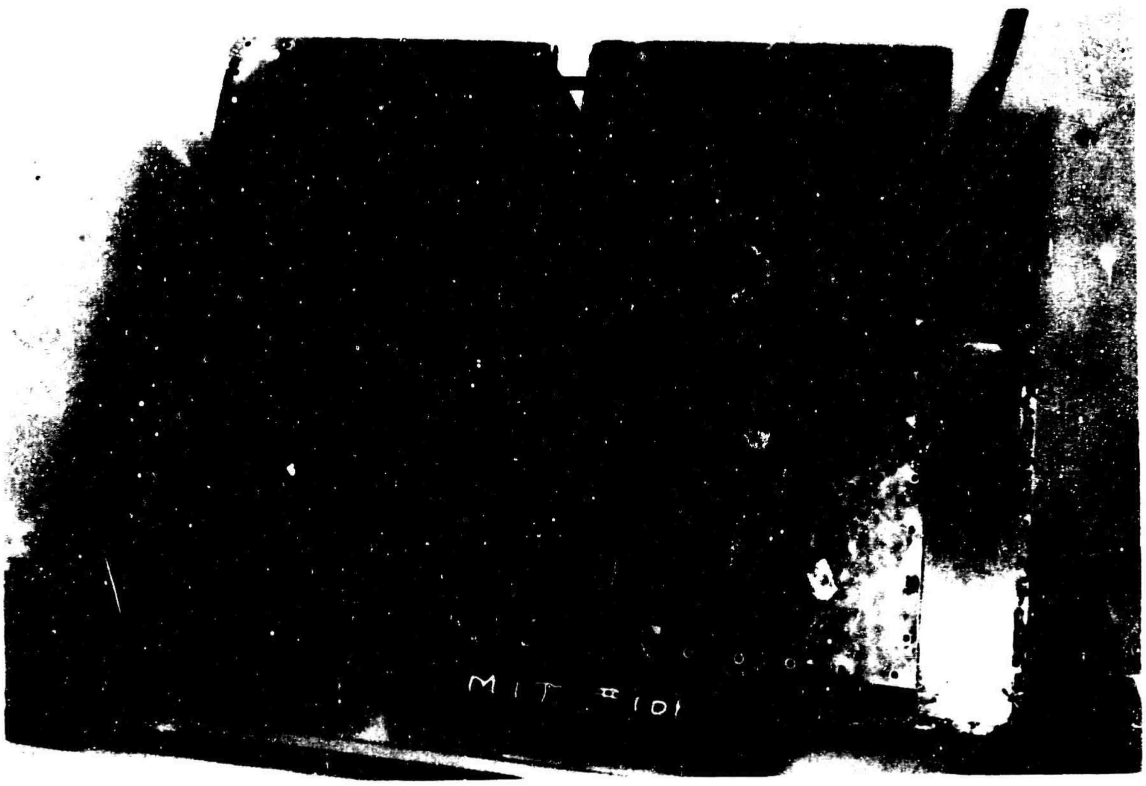

Figure 71. Civilian Collective Protector, MITE2R6

m. Collective Protector MITE2R11.

The MITE2R11 was only the canister of the MITE2R10. It was stripped of all equipment not essential to its use in multiple unit installations.[43]

The MITE2R10 and MITE2R11 models were standardized on 7 October 1943 as the Protector, Collective, M4 and the Canister, Collective Protector, M4A1, respectively.

Figure 72. Civilian Collective Protector, MITE2R6

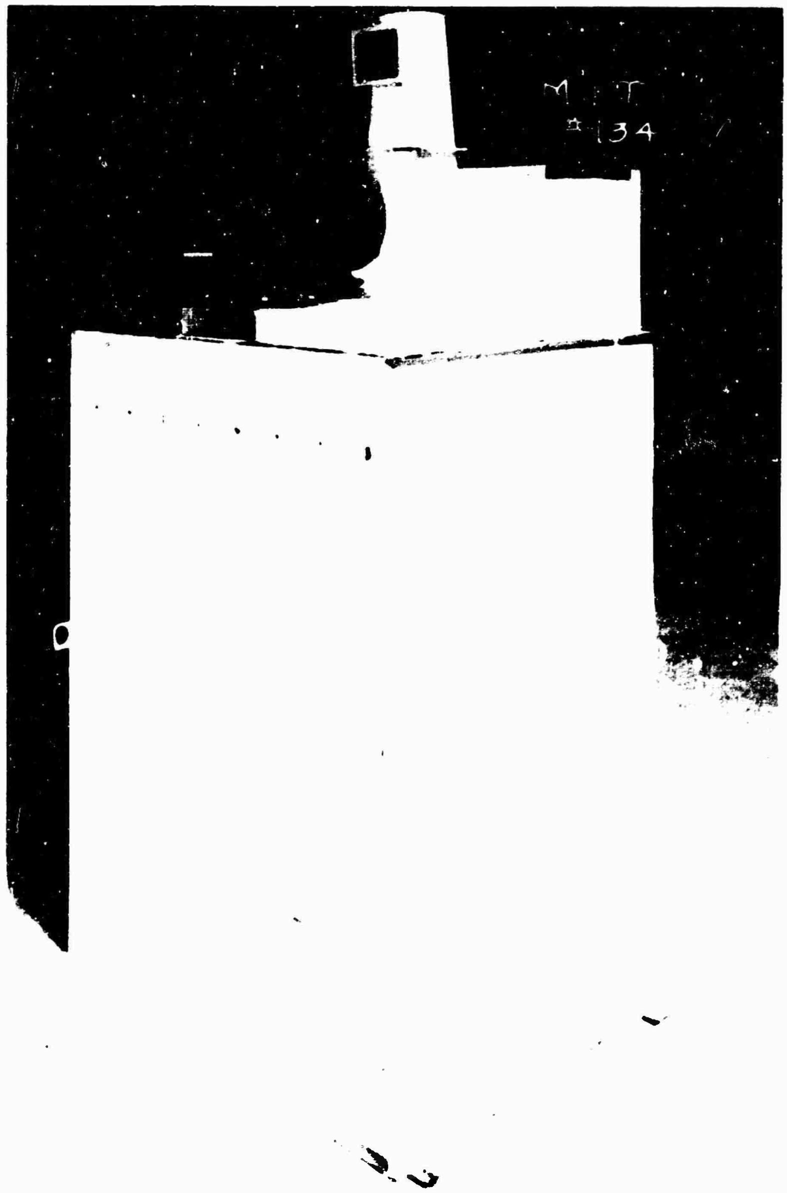

Figure 73. Civilian Collective Protector MITE2R9

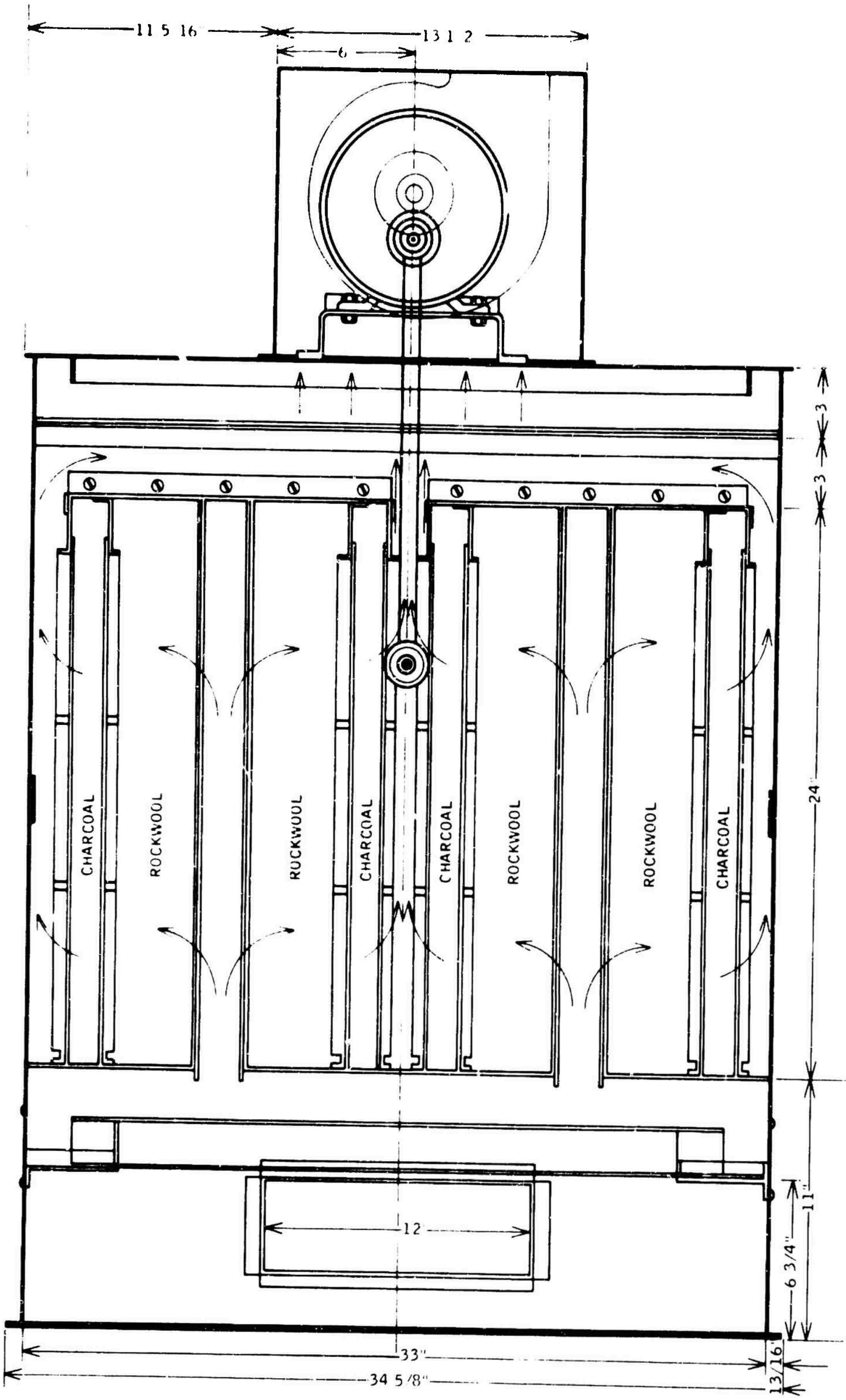

Figure 74. Civilian Collective Protector MITE2R10

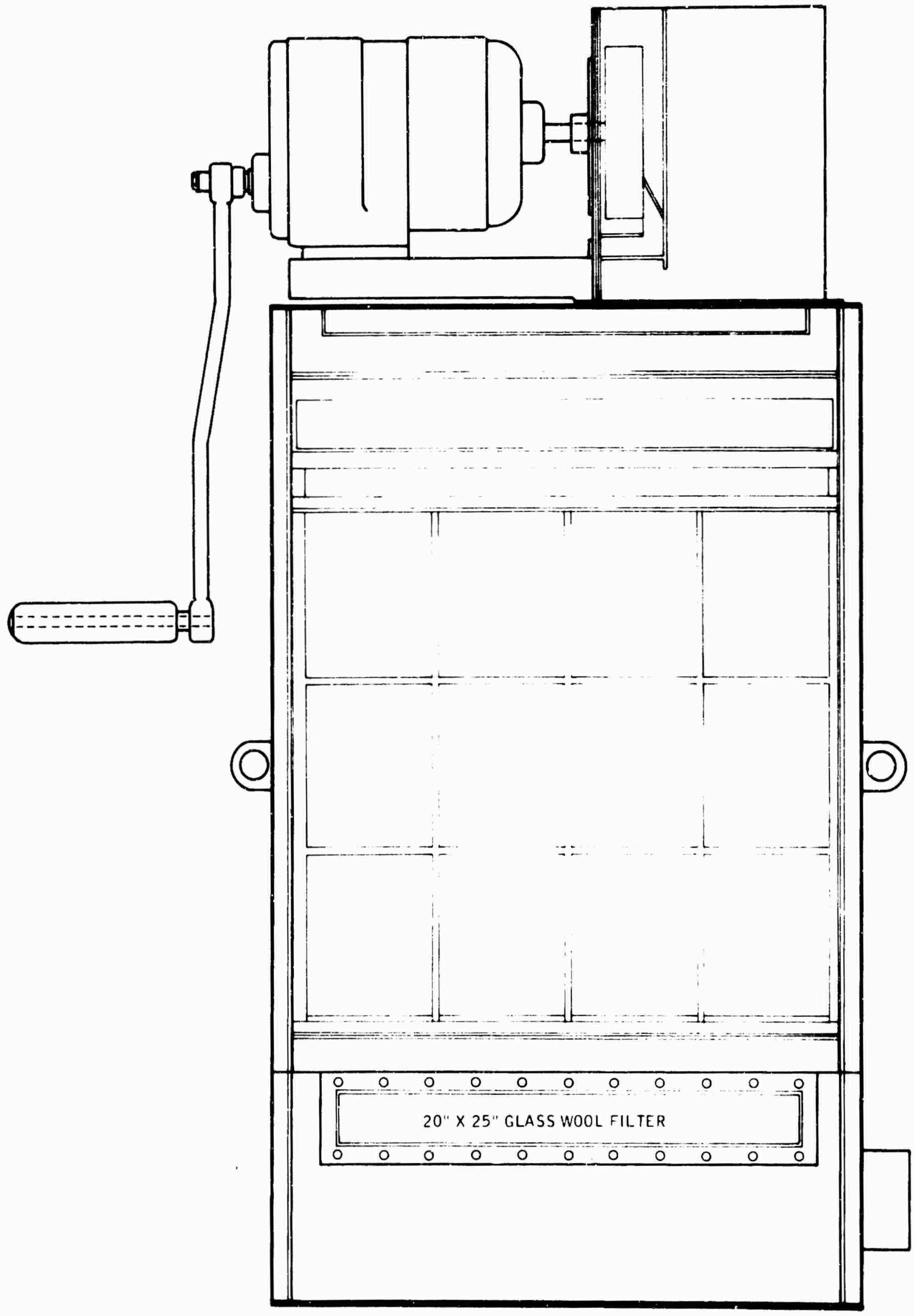

Figure 75. Civilian Collective Protector MITE2R10

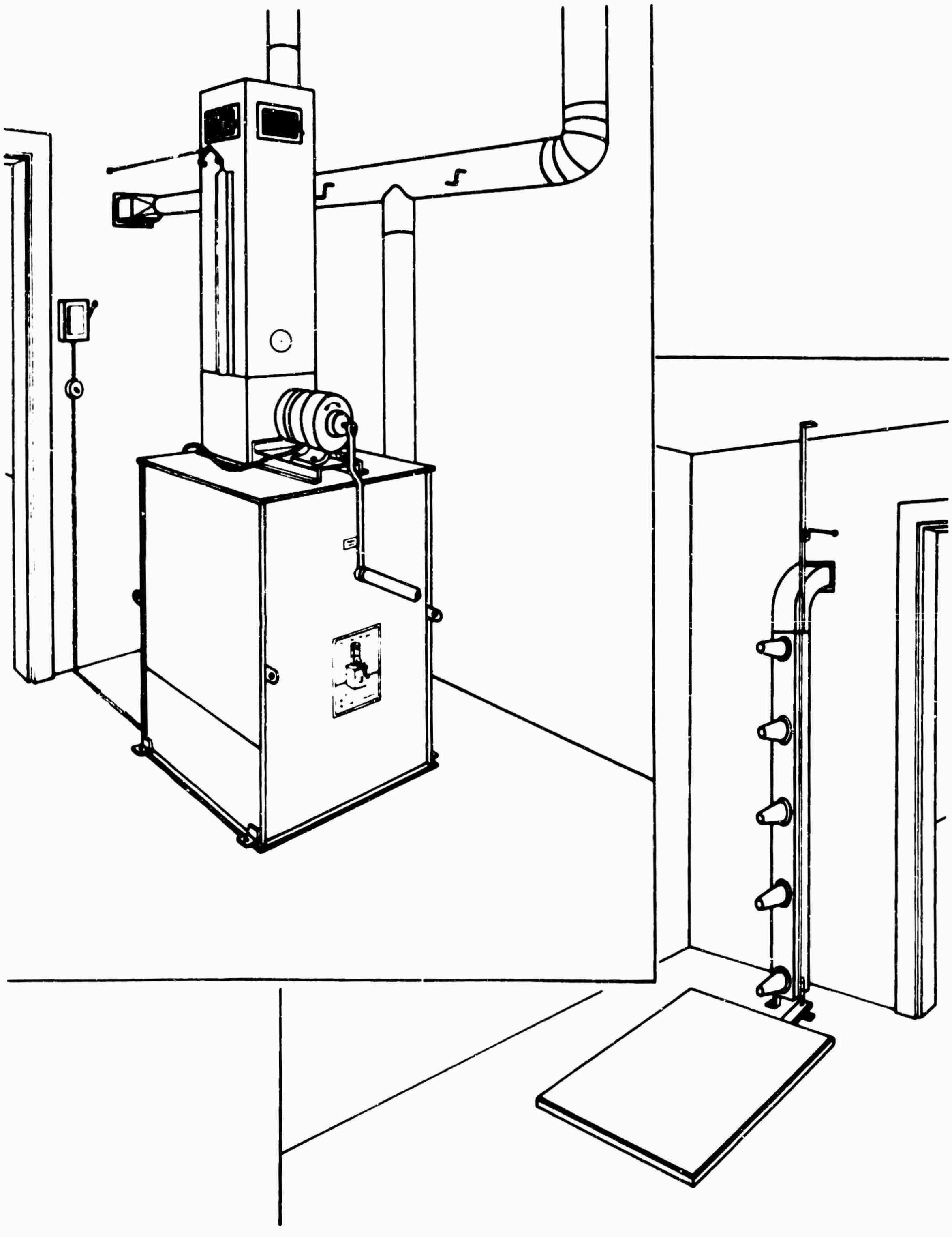

Figure 76. Protector, Collective. Civilian MITE2R10
Operating and Installation Diagram

4. Tests of M4 Collective Protector.

a. The M4 Collective Protector was tested by the Engineer Board and was found to perform satisfactorily. The following is a summary of their test results:

(1) When properly crated, the unit could be safely shipped long distances by commercial carrier without damage.

(2) No channelling occurred within the unit due to shipping as evidenced by the successful purification of gas-laden air in the high concentration chemical reagent test.

(3) The unit will function satisfactorily over an extended period of time.

(4) Sufficient air to allow at least 17 persons to carry out normal command post or plotting room functions without discomfort was supplied when the unit was hand operated.

(5) The airblast was not suitable for decontamination of clothing of individuals exposed to CN under the condition existing during the tests.

(6) The unit was sufficiently rugged to withstand the blast resulting when 5 lb of TNT was exploded at a distance of 15 ft from the unprotected unit. However, the damage resulted from splinters or gravel thrown against the unit by the force of the explosion.

(7) The unit built up a pressure and operated satisfactorily when installed in a 16 by 16 ft pyramidal tent made by gastight as possible.*

b. The M4 Collective Protector was also tested at Edgewood Arsenal. The canister showed good protection against DM, but it appeared that the particular unit tested had a defective charcoal bed which di; not function well against high concentration of CN.[78]

A second series of tests conducted at Edgewood Arsenal showed that the charcoal bed defects found in the first set of tests had all been corrected. The smoke protection against both DM and CN were good.[77,79]

H. Tank Protectors - Pressure Ventilation Type

1. Military Requirement.

A military requirement for a tank protector was established in November 1944 by the Army Service Forces.

2. Military Characteristics.

(a) It should be as small as practicable.

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*Service Tests of Protector, Collective, M4, Engineering Field Report. The Engineering Board, 39, 616. 26 April 1943.

(b) It should be designed so as to cause minimum interference with the functioning of the tank crew during normal operation or during firing.

(c) It should be designed to connect to an outside source of air.

(d) A blower should be provided which is capable of delivering a quantity of purified air which will be sufficient to prevent entry of gas to the crew compartment of an adequately sealed tank.

(e) The blower should be driven by a 24-volt universal motor which can be connected to the tank electrical system.

(f) The protector should be designed so that all air entering the crew compartment passes through the protector canister.

(g) The canister should be provided with a replaceable type dust filter that will remove the dust from the air supplied to the crew compartment.

(h) The protector should provide protection against crash concentrations of nonpersistent chemical agents.

(i) The protector should be designed so that it can be installed in the tank at the manufacturing plant and at the time of manufacture.

(j) Design and function of the gas protective device must be such as to place no undue heat burden upon the crew when operating in a hot, humid climate.

(k) Design of protective equipment must be coordinated with tank design to insure proper fit and operation. Of particular importance are storage, power requirements, and degree of sealing in relation to airflow capacity.[25,27]

3. Models of the Tank Protector.

a. Tank Protector, MITE1.

The MITE1 Tank Protector was designed for use in the T20 tank before the final stowage changes in this vehicle. It consisted of two rectangular canisters mounted on the front slope sheet of the tank, one in front of each driver. Both units were fed from a No. 6 Rotoclone blower mounted between the two drivers and driven by a flexible shaft from the tank engine. The entire assembly was designed for 100 cu ft/min of air delivered at an air resistance of 7.5 in. of water. The adsorbent bed consisted of 3 in. of charcoal the smoke filter was a pad 3/8-in thick of rock wool preceding the adsorbent and 1/8-in. of resin wool following the charcoal. This unit was filled and sealed from the influent end; thus small leaks in the canister seal would cause the issuance of contaminated air into the protected space.

b. Tank Protector MITE1R1.

The MITE1R1 canister shown in figure 77 was similar to the MITE1 except that it was designed to be filled and sealed from the effluent end where the pressure was low and the only air which could leak out through an imperfect seal had already been purified. No further developments were carried out on the MITE1 series of canisters because:

(1) Redesign of the front of the tank eliminated the mounting location.

(2) The front slope sheet was a dangerous spot to mount heavy equipment that might shake loose.

c. Tank Protector MITE2.

Like the MITE1 Tank Protectors, this unit was designed for 100 cu ft/min airflow. Because of the mounting location, however, the design was somewhat different. A photograph of the MITE2 canister is shown in figure 78. Two identical sections, each containing two filter beds in parallel, were bolted to a central feed leaf. Air was fed from an electrically-operated No. 4 Rotoclone, mounted in the tank, into the feed leaf. The air divided in the leaf, 50 cu ft/min going into each section of the canister. Inside the canister the air again split, part flowing upward and part downward, through 3/8-in. pads of highly compressed rock wool, 2-in. beds of charcoal, and 1/8-in. pads of resin wool. The upper outlet face of each section was 6 by 22 in. and the lower outlet face was 10 by 22 in. Each half canister was designed for 50 cu ft/min airflow or a total of 100 cu ft/min for the entire assembly. The total face area was 704 sq in. These areas were baffled with 1/2-in. baffles on both sides of the charcoal beds.[56]

d. Tank Protector MITE2R1.

This unit was identical with the MITE2 Tank Protector, except that it was 1/2-in. higher to permit the use of 2-1/4-in. deep charcoal beds instead of 2-in. layers.[56]

e. Tank Protector MITE2R2.

The MITE2R2 Tank Protector used an unsymmetrical assembly. Figure 79 shows the parts of the MITE2 and MITE2R2 canisters. Parts A and B with the center fed lead form the MITE2 and parts A and C with the center feed leaf form the MITE2R2. The outlet dimensions of part C and 11 by 22 in.; in all other respects it was identical with parts A or B. The MITE2R2 unit, because of its greater area, was suitable for the purification of 130 to 150 cu ft/min of air, whereas the MITE2 was designed for only 100 cu ft/min. The sloping sides of parts A and B of the MITE2 and MITE2R2 protectors made filling extremely difficult. In addition a perfect edge seal of the filter against the slope was nearly impossible.[56]

Figure 77. Tank Protector Canister MITE1R1

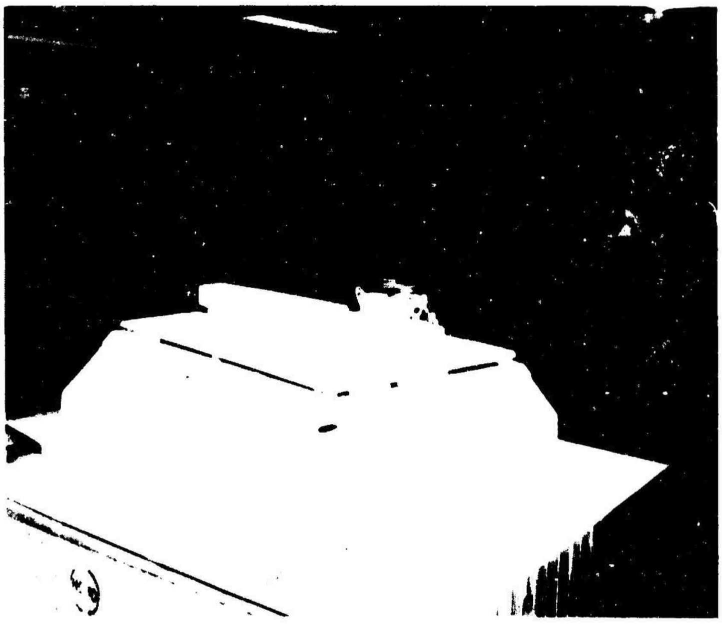

Figure 78. Tank Protector Canister, MITE2

f. Tank Protector, MITE2R3.

The protector assembly MITE2R2 was designed to overcome the difficulty of the sloping side of the MITE2 unit. This protector was similar in construction to the MITE2 with the exception that it had a stepped side in lieu of a slope. Figure 80 shows a half canister which was built in the laboratory for test, and figures 80 and 81 show the internal construction. Two such units and a feed leaf composed the MITE2R3 Tank Protector. The overall dimensions including the area of the outlet faces were the same as the MITE2R1.

This unit was easy to fill and assemble. All of the major difficulties with the former units were eliminated. With the exception of the canister height the unit shown in figure 78 was modified internally to the MITE2R3 design and forwarded to the General Electric Company for installation in one of the pilot T23 tanks. The first time this unit was run in a moving vehicle the rock wool smoke filter became plugged with dust.[56]

g. Tank Protector, MITE2R4.

This tank protector was an unsymmetrical assembly using a half canister of the MITE2R3 type, and a rectangular half canister like part C in figure 79.[56]

h. Tank Protector, MITE2R5.

This canister was identical to MITE2R3 Tank Protector, except that it was 1-in. higher to allow space for "slide-in", replaceable dust filters. These dust filters were approximately 1/4-in. thick, and the same area as the outlet faces. Slots were cut into one end of each canister so that these filters could be inserted between the inlet plenum and the smoke filter. After insertion of the filter, the openings were covered with a gasketed metal plate. The construction of the filter and method of sealing it in the canister were discussed under MITE2R7 Tank Protector.

All canisters of the MITE2 series through MITE2R5 were designed for installation in the T23 tank.

i. Tank Protector, MITE2R6.

This protector was designed for use in the T22 tank which was being developed by the Chrysler Corporation. Figure 82 shows a diagramatic sketch of a half canister of this protector, and figure 83 is a sketch showing the installation in the vehicle. Internal dimensions and filling were identical with the MITE2R5 unit, but the outside dimensions are as shown in figures 84 and 85. A half canister following this general configuration was constructed by the Chrysler Corporation, but because the size was materially reduced, the air resistance was high.

j. Tank Protector, MITE2R7 (for M4A3 Tank).

This air purifier was a two canister assembly using a rock wool smoke filter and a 2-in. deep charcoal bed. Figure 86 shows the assembled protector. The internal construction of

Figure 79. Tank Protector Canisters MITE2 and MITE2R2

A. and B. Parallel flow units with the upper outlet face of each section 6 by 22 inches and the lower outlet face 10 by 22 inches; and C. parallel flow unit with top and bottom outlets 11 by 22 inches.

Figure 80. Tank Protector Canister MITE2R3

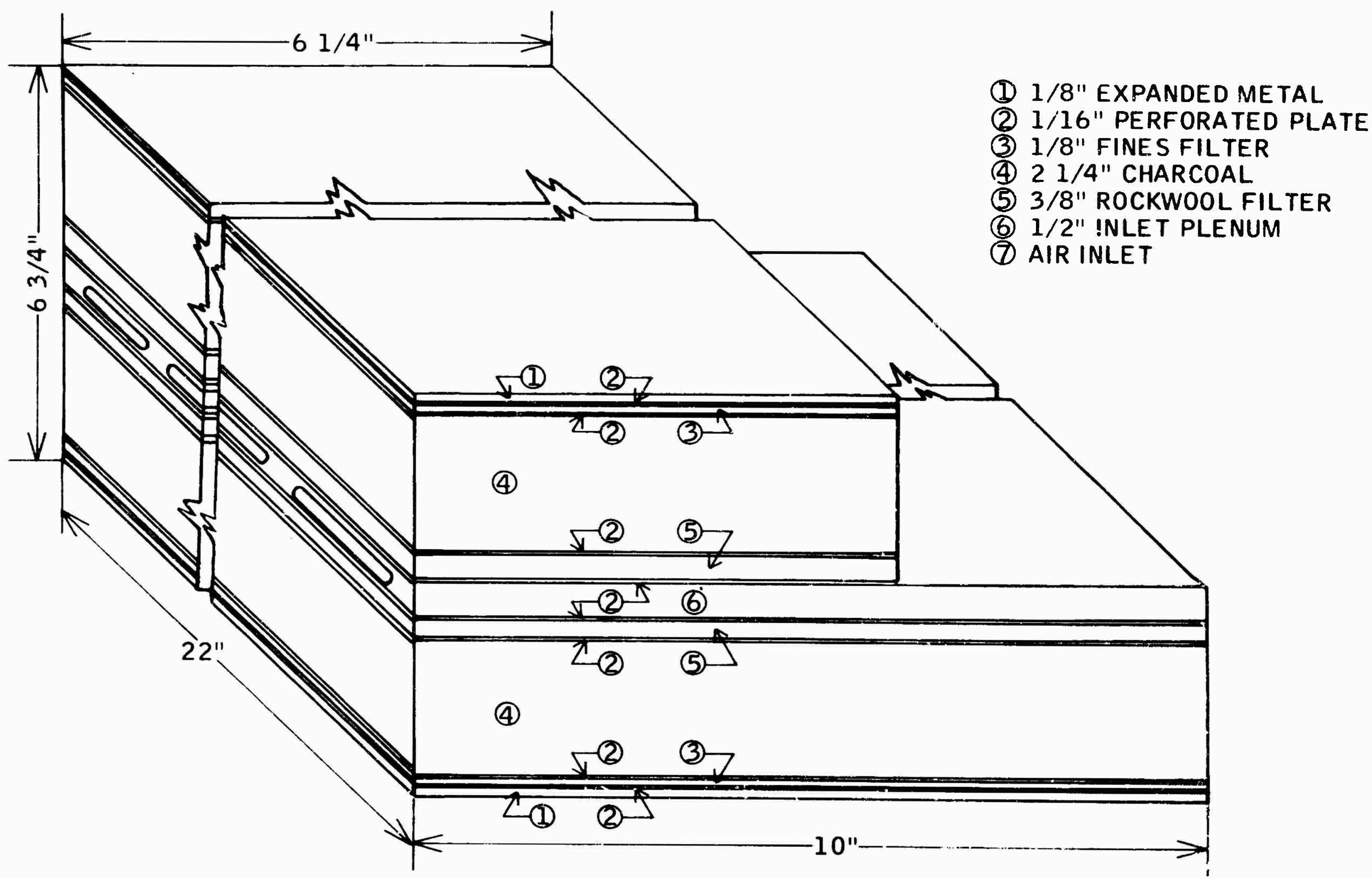

Figure 81. Arrangement of Components of Model E3 Tank Protector E7a-3

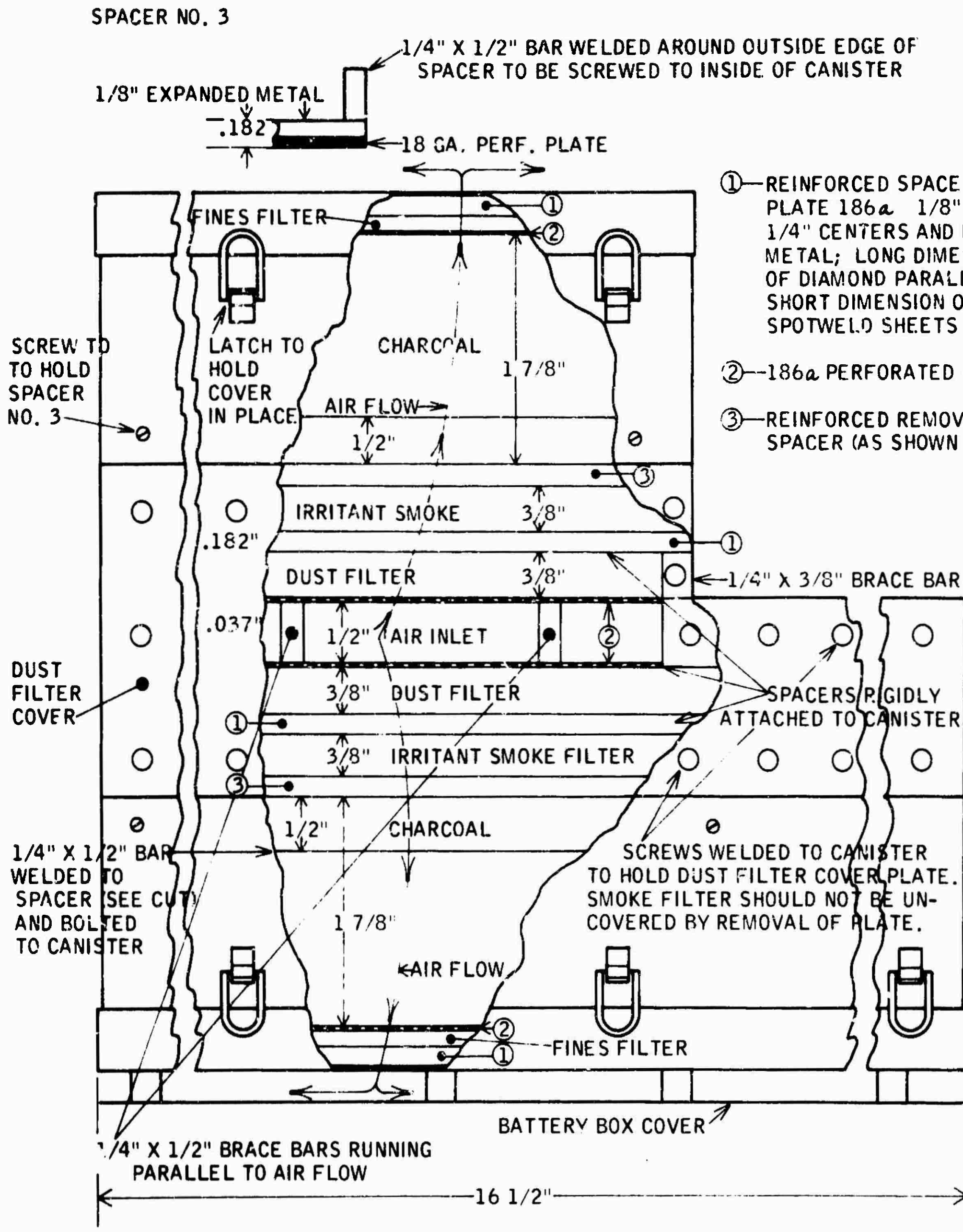

Figure 82. Diagrammatic Sketch of One Half Canister of MITE2R6 Tank Protector

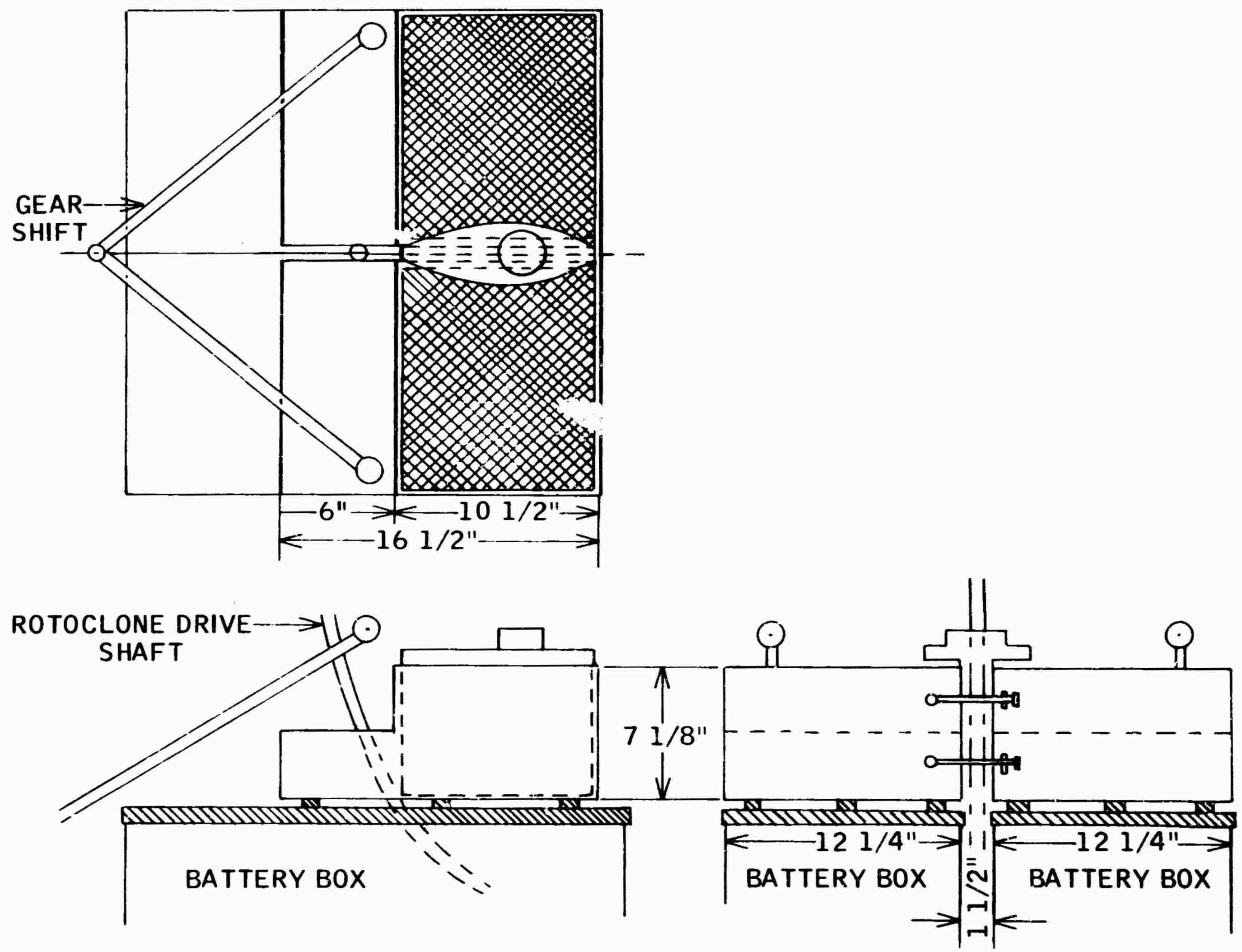

Figure 83. Two Unit Air Purifier for Tank T22

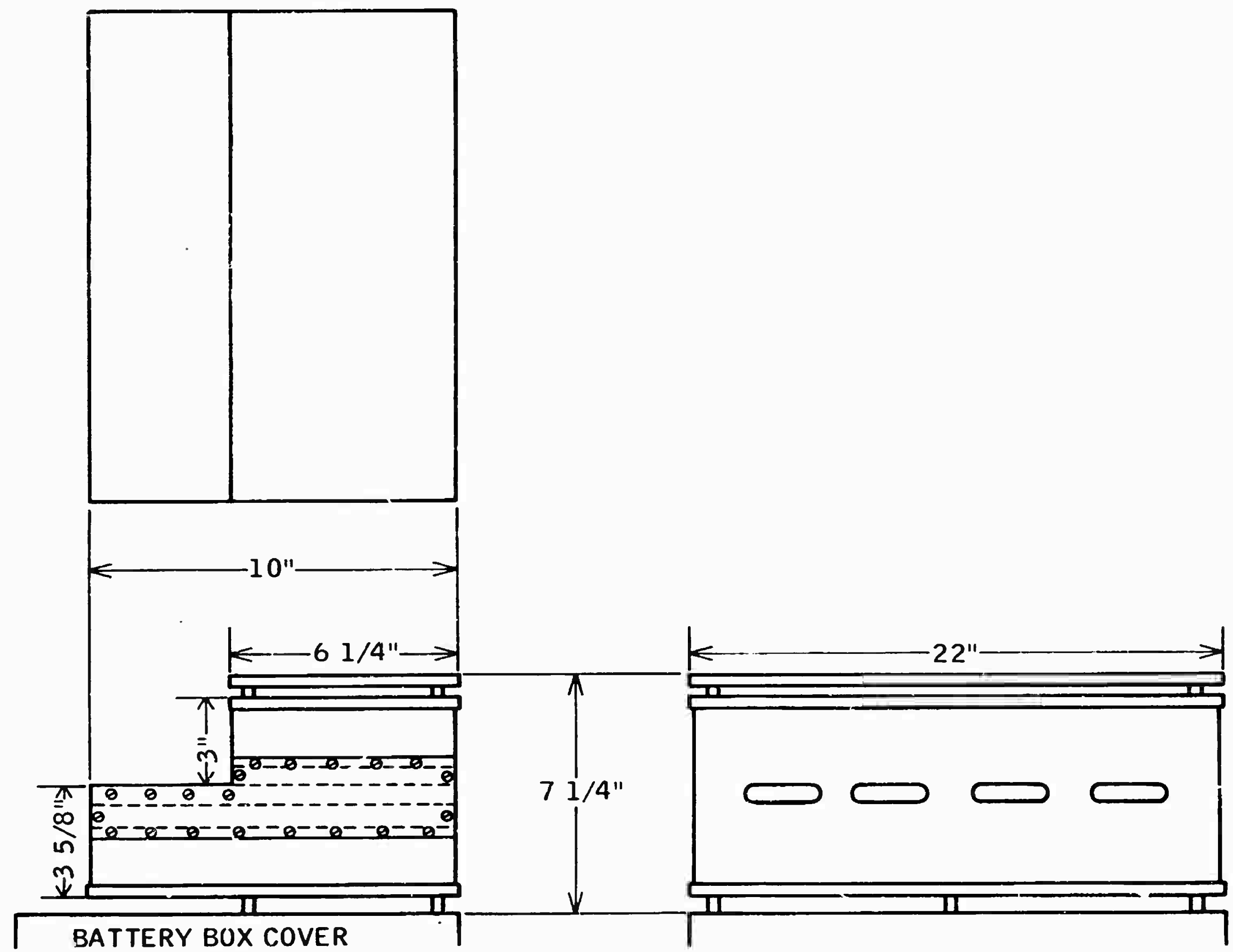

Figure 84. Air Purifier for Tank Showing Dust Filter Cover Plate

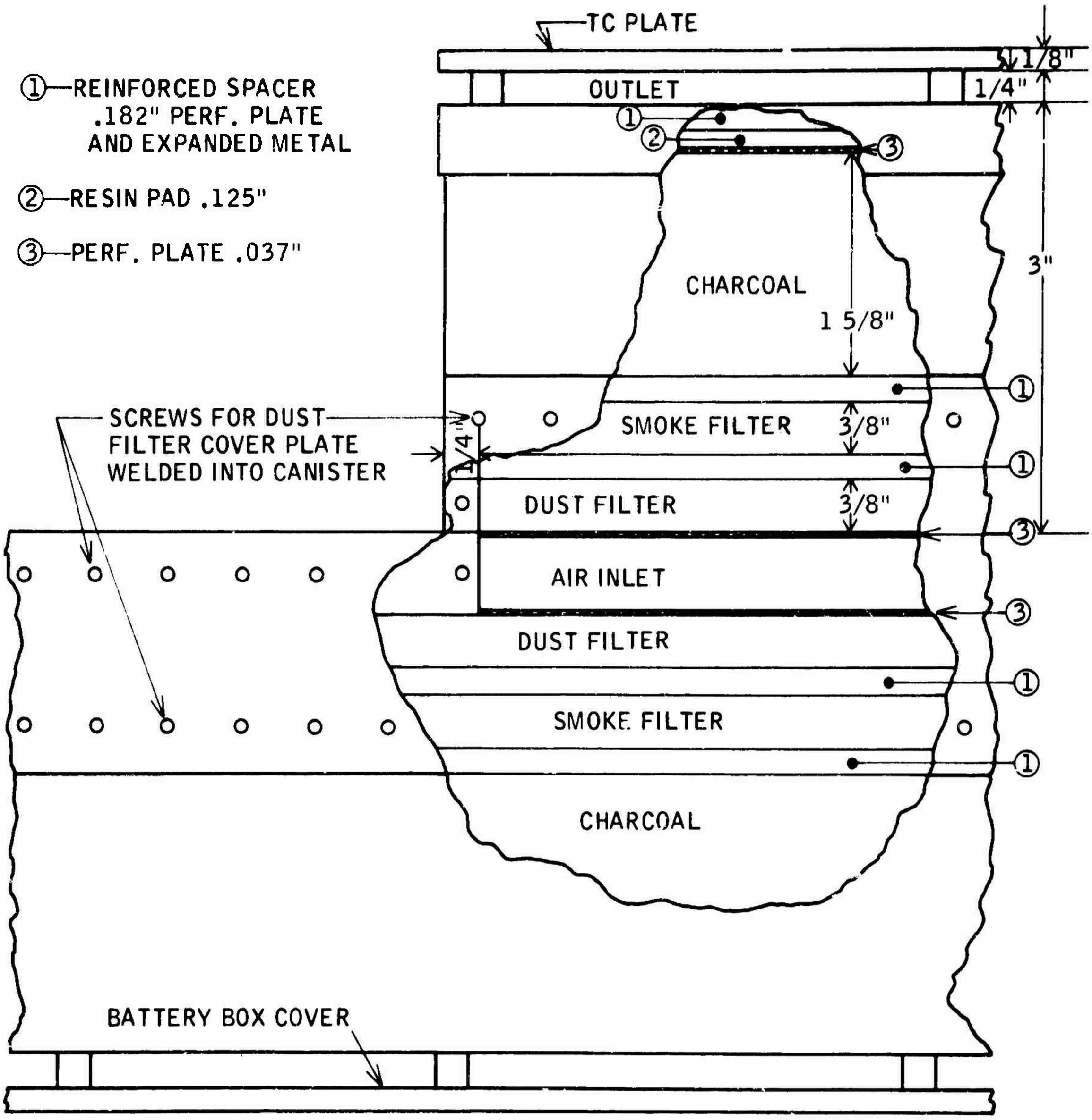

Figure 85. Air Purifier for Tank Internal View

one of the canisters is shown in figure 87. Air entered the central plenum, divided into two streams, each of which passed successively through the dust filter, smoke filter, charcoal bed and fines filter, then into the protected space. The total design airflow for the two-canister assembly was 200 cu ft/min.[56]

k. Tank Protector, MITE3.

This unit was never constructed or tested.

l. Tank Protector, MITE4.

The Tank Protector MITE4 was designed for installation in the T20 tank. Figure 88 shows the filled and assembled unit ready for installation in a vehicle. It consisted of a centrally-fed, cylindrical canister, pleated-felt dust filter, wrapped-on-paper smoke filter, 2-in. radial charcoal bed, and wrapped-on fines filter. An adapter was supplied to attach to the Rotoclone outlet and a tube connected the adapter and canister. Figure 89 shows the internal structure of the canister.[56]

m. Tank Protectors, MITE5, E6, E7.

These refer to facepiece protector canisters.

n. Tank Protector, MITE8.

This canister was designed for installation on the battery boxes between the two drivers of the final model T23 tank and was constructed specifically for a series of physiological heat-loading tests, conducted in July 1944 at Camp Polk, Louisiana.

The canister was constructed in four separate sections, two charcoal containers, a double-filter section serving as both a smoke and dust filter for each charcoal layer, and an inlet plenum. Each part was constructed from welded 18-gage steel and was copper-plated after fabrication. The canister was held together by tie bolts and the inlet plenum was secured by thumb bolts running through tubes welded into the plenum. Figure 90 shows the assembly canister and figure 91 shows the canister mounted in the T23 tank.

This canister was not designed for a specific airflow but was constructed to yield the minimum resistance and maximum airflow consistent with the available installation area and characteristics of the blower installed in the vehicle.

The central filter section of the canister contained two pleated paper filters consisting of straight pleats of Type 6 paper separated by cardboard combs and arranged for parallel flow. This section served as both a smoke and dust filter and was replaceable as a complete unit.

The two axial-flow charcoal containers mounted on either side of the filter section contained 2-1/8-in. beds of Grade L, Type ASC (Whetlerite) charcoal and thin resin-wool fines filters.[56]

Figure 86. Tank Protector, Canister, MITE2R7

4. Tests.

a. Test of a Pressure Ventilated M4A3 Tank.

A tank collective protector comprising two MITE2R7 canisters was set up in an M4A2 tank. Various gas, smoke, and dust tests were conducted. The gas and smoke protection afforded the crew members was very good. In fact, it was believed that the gas life was probably in excess of tank requirements.

The dust life of the canister between filter changes was found to be inadequate and filter replacement was too difficult and time-consuming.

The ventilation system used caused positive pressure to exist between the Rotoclone blower outlet and the canister outlet. This situation was dangerous since small leaks in the assembly would permit the entry of contaminated air into the crew compartment.

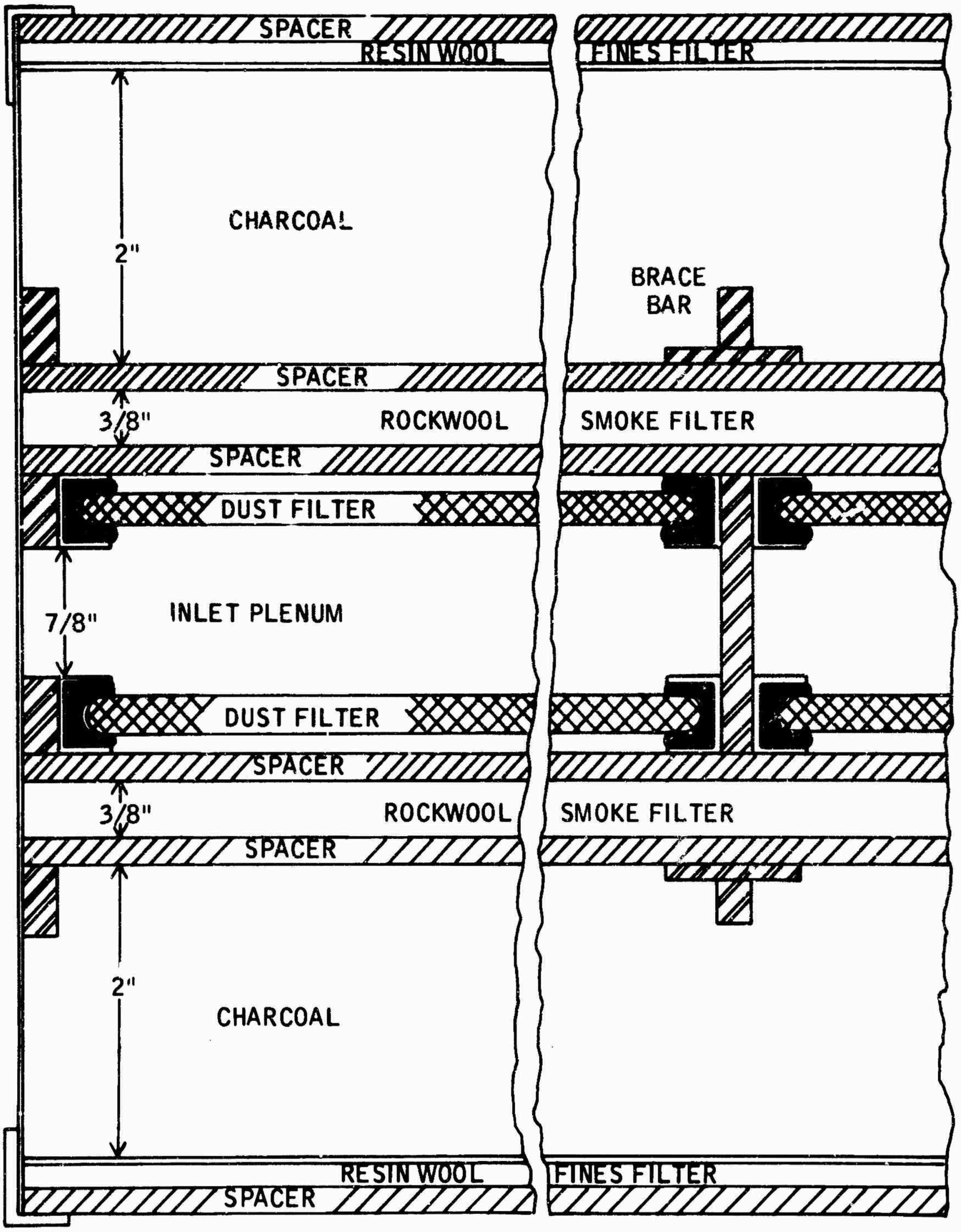

Figure 87. Tank Protector, Canister, MITE2R7, Internal Construction

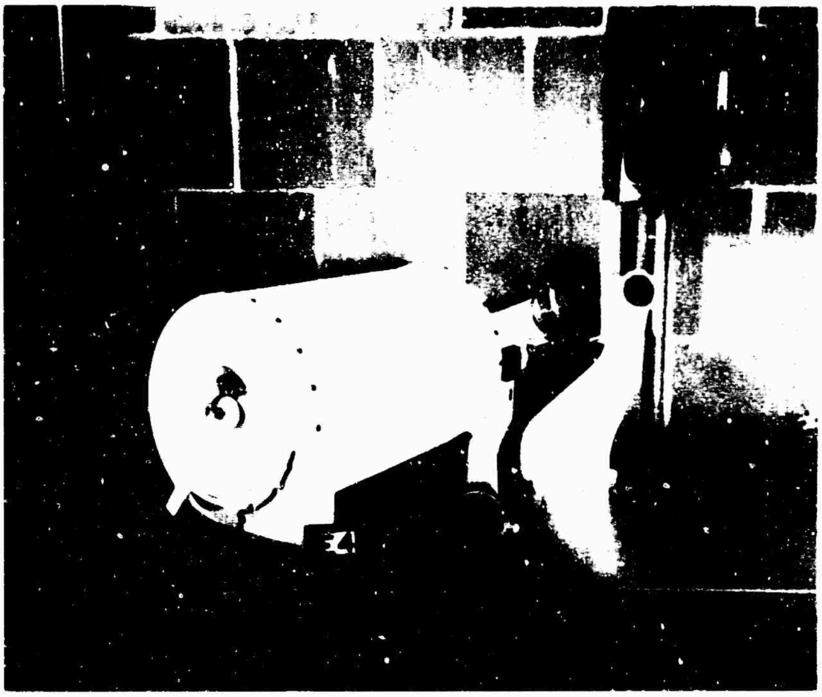

Figure 88. Tank Air Purifier MITE4

The flow of 200 cu ft/min was adequate to produce a pressure in excess of 1.0 in. of water in an M4A3 tank sealed as in these tests. However, it was believed that 200 cu ft/min of air was insufficient to produce adequate ventilation for comfort either for extended periods of operation or even for short periods in warm humid climates.[31]

b. Heat Loading Tests.

The MITE8 Tank Protector Canister was installed in a T23 tank. It delivered 275 cu ft of air per minute producing a pressure of 3/4 in. H_2O in the tank crew compartment. It was felt that this complete system of tank protection provided the best solution to the problem, but it was not considered to be adequately developed as yet. One objection was the excessive temperature in the turret due to poor air distribution.*

*Final Report on Project No. 35. Determination of the Optimum Method for Protection of Tank Crews Against Chemical Warfare Agents. 13 September 1944. Armored Medical Research Laboratory.

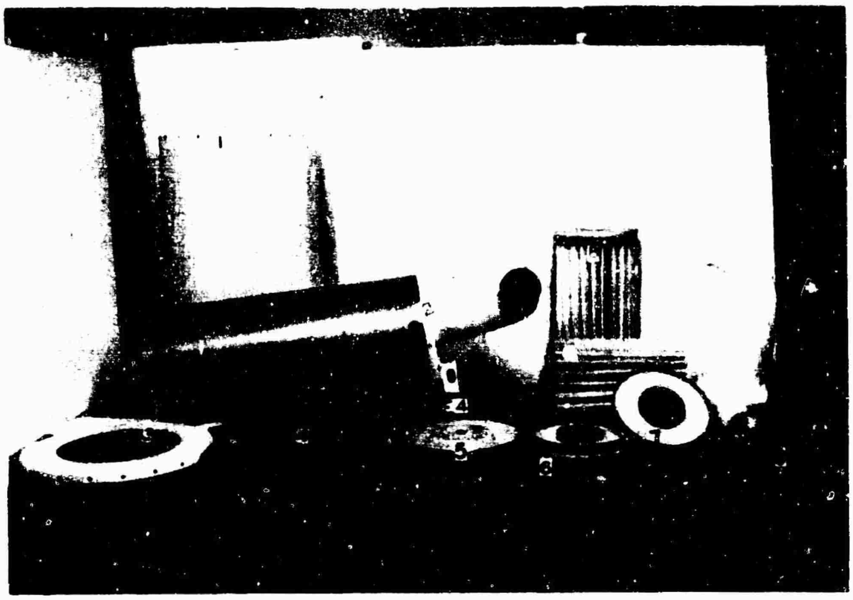

Figure 89. MITE4 Tank Air Purifier

(1) Outer cylinder containing fines filter; (2) inner body. Dust filters occupy cavity around inner tube, smoke filter is on outer tube, charcoal is poured between outer tube and outer cylinder (1) after assembly; (3) end bracket and cover; (4) end seal gasket; (5) dust filter cover and gasket; (6) miscellaneous nuts, screws, etc.; (7) dust filter and plate; (8) assembled dust filter; and (9) inlet pipe.

Facepiece Protector.

1. Military Requirement.

A military requirement for tanks included the facepiece protector as a "field fix" system of tank protection. The requirement was set up by the Army Service Forces.

2. Military Characteristics.

(a) It should be primarily designed for installation in combat vehicles.

(b) It should be as small as practicable.

(c) It should be designed so as to cause minimum interference with the functioning of the combat vehicle crew during normal operation or during firing.

(d) It should be designed to connect to a source of outside air.

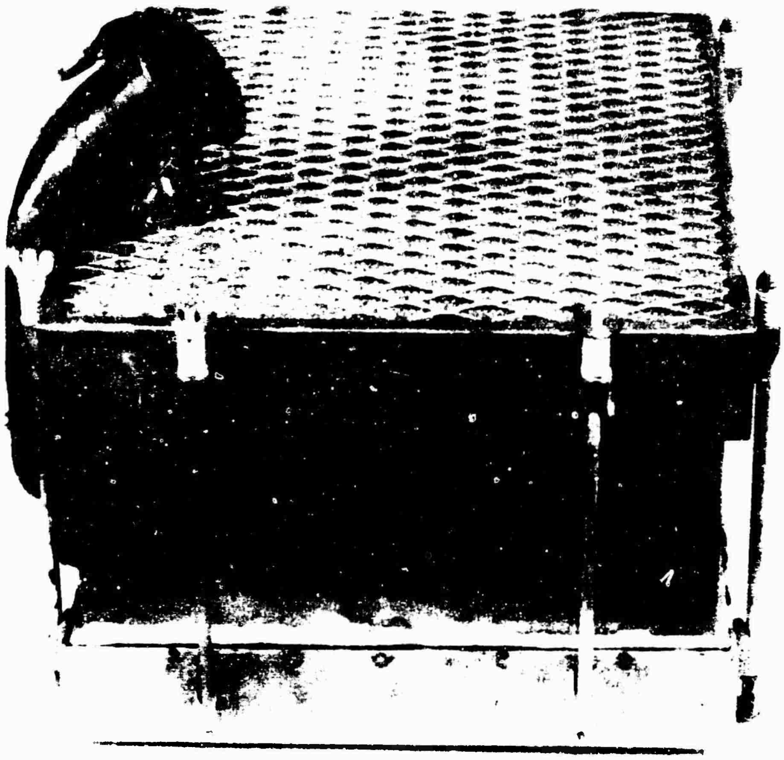

Figure 90. Tank Protector, MITE8

(e) A blower should be provided which is capable of delivering to the protector canister a minimum of 4 cu ft/min of air per crew member.

(f) The blower should be powered by either a 24-volt dc motor or a 12-volt universal motor.

(g) Provision should be made for delivery of all purified air through flexible tubing to loose-fitting, light-weight, full-vision facepieces worn by individual crew members.

(h) A dust filter should be provided which has a minimum life equivalent to that of the combat vehicle engine air cleaner.

(i) The protector should provide protection against crash concentrations of nonpersistent chemical agents.

Figure 91. Tank Protector, MITE8
(mounted in tank)

(j) The canister and dust filter should be designed so that they can be quickly and easily replaced.

(k) The protector should be sufficiently simple in design so that it can be readily installed by 4th echelon maintenance personnel.

(l) Design and function of the gas protective device must be such as to place no undue heat burden upon the crew when operated in hot, humid climate.

(m) Design of protective equipment must be coordinated with tank design to insure proper fit and operation. Of particular importance are storage and power requirements.[25,27,28]

3. Facepiece Protector Models.

a. This design using several smaller standard air purifier units (e.g., horse gas-mask air-purifier tubes, M9A2 Canister, or M11 Canisters) as originally developed by the Canadians, was given preliminary consideration, but was too bulky and heavy for the protection afforded.[30]

b. Facepiece Protector, E21.

The E21 Facepiece Protector, was the first model designed using a special canister and was the unit used during the field tests at El Centro, California, discussed below. Through this test and succeeding laboratory studies, this unit proved the possibility of protecting armored vehicle crews from chemical warfare agents by a "ventilated facepiece" system.

The E21 Facepiece Protector was essentially the same as the final model E21R3, shown in figure 92, except that the canister clamps were somewhat more fragile; no switch cup was used and the mounting lugs were not as strong as on the E21R3 model. The canister used with this item, shown in figure 93, was of slightly different construction and employed an asbestos-wool, resin-wool smoke filter instead of a pleated-paper filter.

The entire assembly is shown in figure 94. During the early stage of development, various facepiece carriers were tried. This figure shows both a metal-can type (later standardized) and a canvas-bag type.

The air purifier, which operated on 24 volts dc, drew about 7.5 amp, and delivered 18 cu ft/min of air against a pressure head of 18 in. of water. This high static pressure was required to overcome the airflow resistance of the system.[30]

c. Facepiece Protector, E21R1.

This unit made use of the canister clamp and canister standardized for the final protector. The unit body itself was, however, not sufficiently rugged to withstand rough handling. The entire assembly is shown in figure 95.

The motor of this unit operated on 24 volts dc, drew about 7 amp, and delivered 18 cu ft/min of air against a pressure head of about 13 in. of water.

d. Facepiece Protector, E21R2.

This protector was identical in every respect with the E21R3 model except that a dual voltage (12/24) motor was used, as suggested by the Ordnance Department. This motor drew 7.0 amp at 24 volts and 14 amp at 12 volts, delivering 15 cu ft/min of air against about 8 in. of water pressure. The high current drain at the lower prescribed flow and static pressure was caused by the inherent inefficiency of the dual voltage motor. This unit was not acceptable to the Ordnance Department because of the high power consumption; this necessitated the redesign of the final model to incorporate a simple voltage motor.[30]

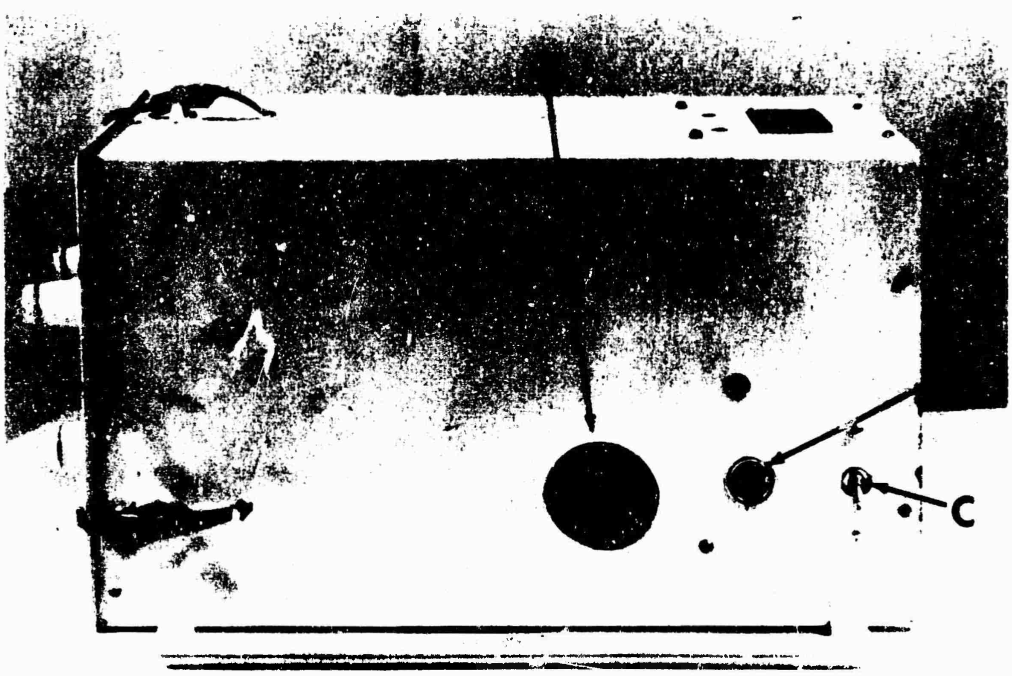

Figure 92. Protector, Facepiece, E21

A. Air inlet; B. canister outlets; C. switch; and D. electrical connections.

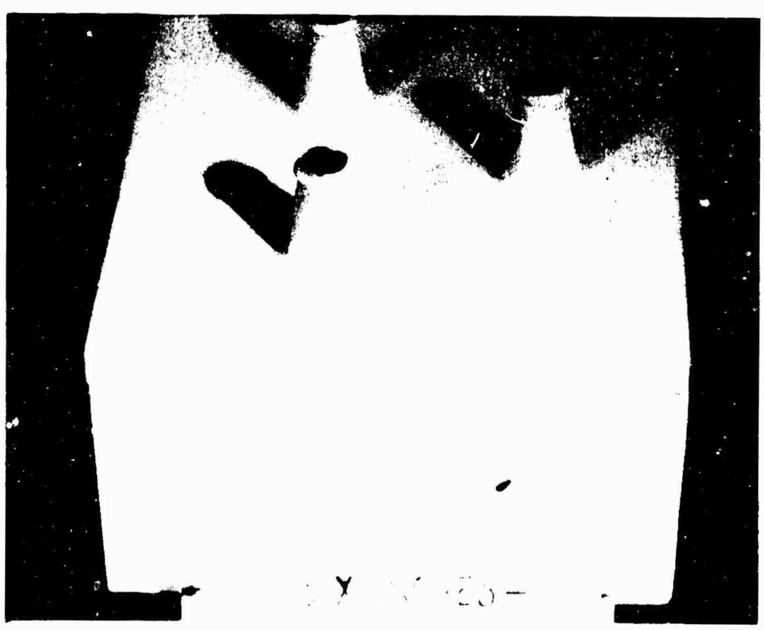

Figure 93. Tank Protector Canister, MITE7

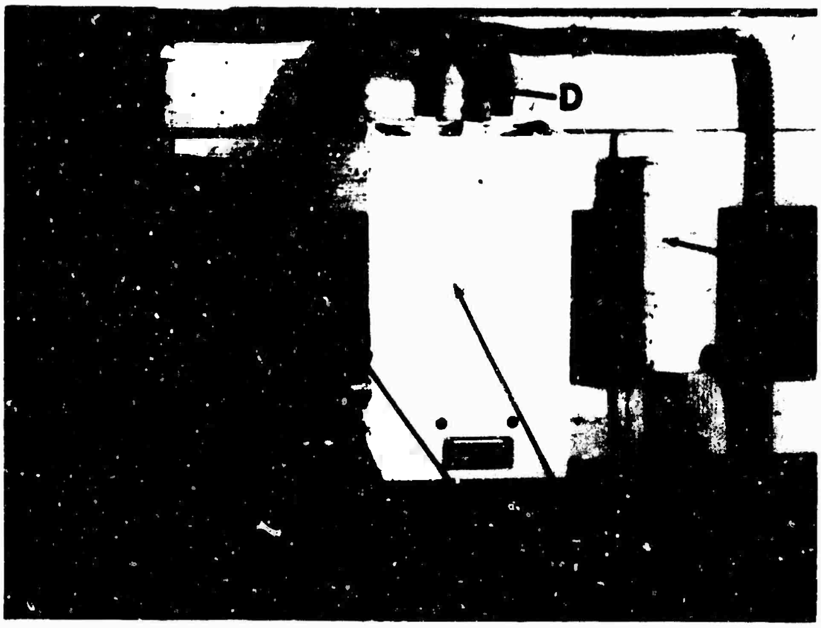

Figure 94. E21 Facepiece Protector Setup in the Laboratory

A. Air purifier assembly; B. inlet hose; C. electrical connection; D. outlet hose; E. facepiece carrier (metal); F. facepiece carrier (canvas); and G. facepiece.

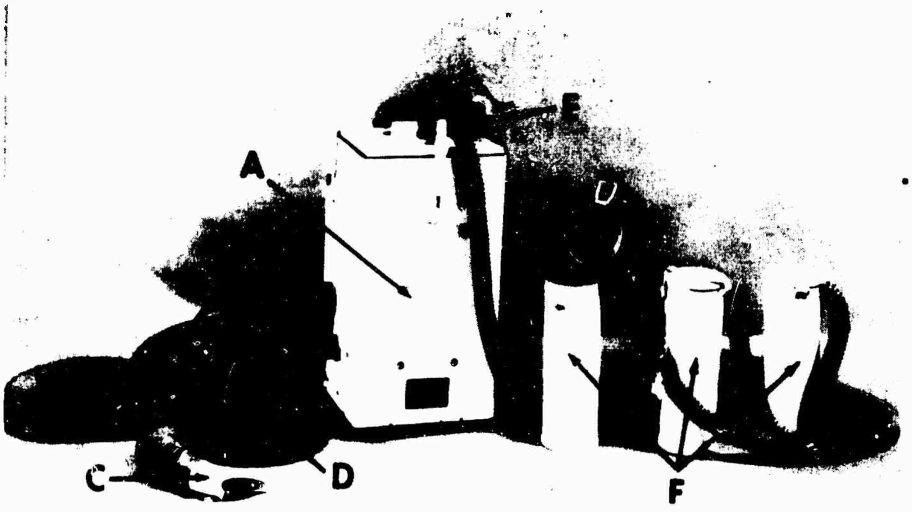

Figure 95. Protecto:, Facepiece, E21R1

A. Air purifier assembly; B. inlet duct; C. ventilator adapter; D. electric cable; E. outlet hoses; and F. facepiece carriers.

e. Facepiece Protector, E21R3.

The air purifier assembly is shown in figure 96. The outside dimensions of the metal container including mounting lugs, inlet ferrule, canister clamps, and nozzles were 17-3/4 by 10-1/2 by 9-1/2 in. When installed, small spaces were left at the back of the unit for dust discharged, at the side of the unit to reach the switch, and about 6 in. at the front for removal of the canister. Figure 97 shows the air purifier with canister and dust filter removed. The blower precleaner was situated behind the bulkhead. Air from the precleaner was discharged into the plenum below the dust filter through the deflector shown on the bulkhead. The rear of the air purifier is shown in figure 98. Dust from the dust dumps of the precleaner was discharged from the deflector on the rear cover plate.

Two views of the blower-precleaner assembly are shown in figures 99 and 100. The motor operates on 24-volt dc supply and drew a current of 3.2 amp. The operating speed at 24 volts was approximately 11,000 rpm. The blower delivered 15 cu ft/min of air at a discharge pressure of 9.5 in. of water. An exploded view of the blower precleaner for the E21R1 Protector is shown in figure 101.

The dust filter is shown in figure 97. It consisted of a filter cell containing felt, meeting the CWS Specification 197-52-107, and its overall dimensions were 8 by 8 by 2 in.

Figure 97 shows the completed canister. Its overall dimensions were 8-1/8 by 8-1/8 by 5-15/16 in., and its weight was 11.8 lb. It contained 2235 ml of 12-30 mesh grade I ASC charcoal in a 2-1/8-in. bed. The smoke filter made from type 6 filter material was a shell-type pleated filter 7-5/8 in. in diameter and 1-3/8-in. high. Fines filters of a combination of resin wool and glass-battery matting have been used to date, but future canisters for the E22 Three-man Facepiece Protector were to have fines filters of Filtocott No. 1,101 manufactured by Johnson and Johnson Surgical Dressings, and cotton scrim secured between baffles as shown in figure 102. Figure 35 shows the components of this gas canister.

One cable assembly (figure 103) was supplied with each unit. The inlet duct and ventilator adapter are shown in figure 103.

Three 6-ft lengths of corrugated rubber hose were part of each unit as were three full-vision facepieces (figure 104). The facepiece fitted very loosely and permitted air to escape along the periphery. Three cylindrical felt-lined sheet-metal canisters (figure 105) were supplied as carriers to protect the facepieces when not in use.[30]

f. Facepiece Protector, E21R4.

The E21R4 Facepiece Protector differed from the E21R3 unit only in that the blower was run by a 12-volt universal motor which was mounted in a slightly different fashion.[80]

g. Facepiece Protector, E22.

All of the E21 series of Facepiece Protectors consisted of two units, as described above, for use by five or six men in a tank. The E22 Facepiece Protector was for use by three men (half of an E21R3 unit for 3 men).[80]

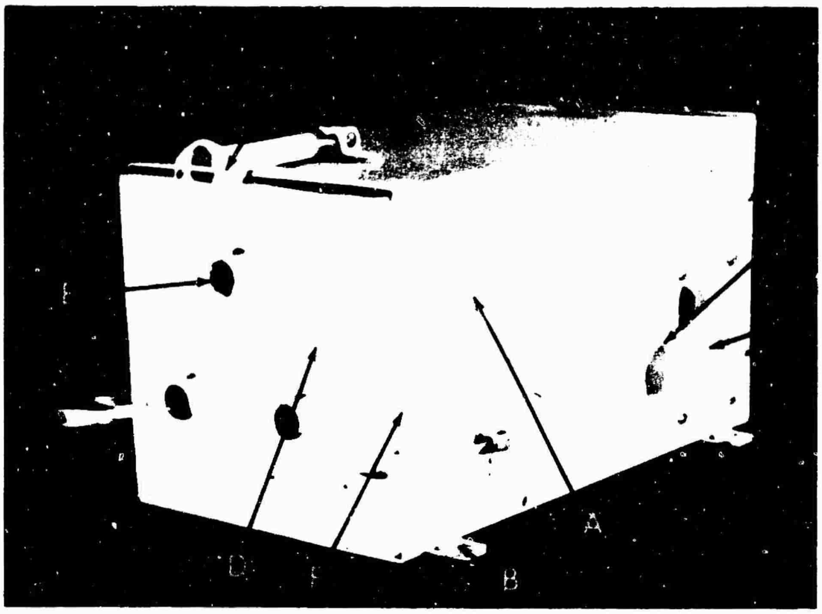

Figure 96. Protector, Facepiece, E21R2

A. Housing; B. mounting lugs; C. canister clamps; D. canister; E. nozzle; F. clamping rim; G. air inlet; and H. switch cup.

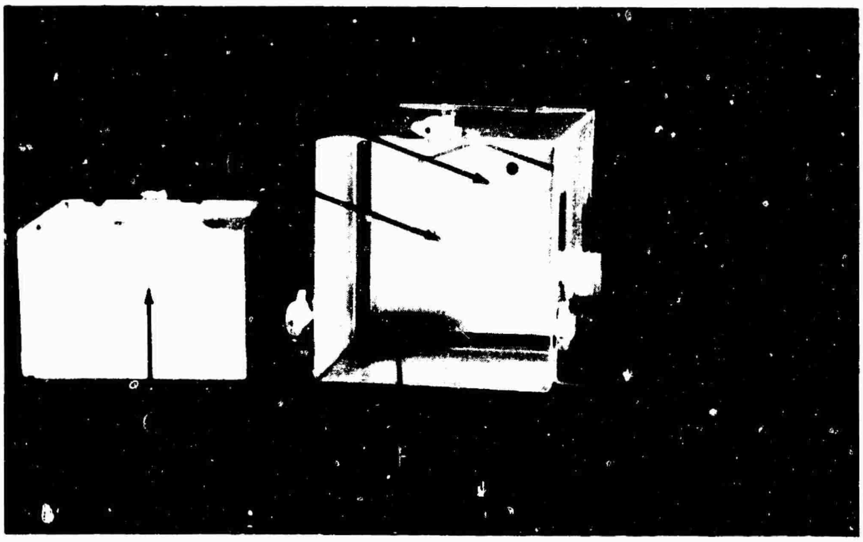

Figure 97. E21R2 Facepiece Protector with Canister and Dust Filter Removed

A. Housing; B. dust filter; C. canister; D. bulkhead; E. bulkhead deflector; and F. bulkhead gasket.

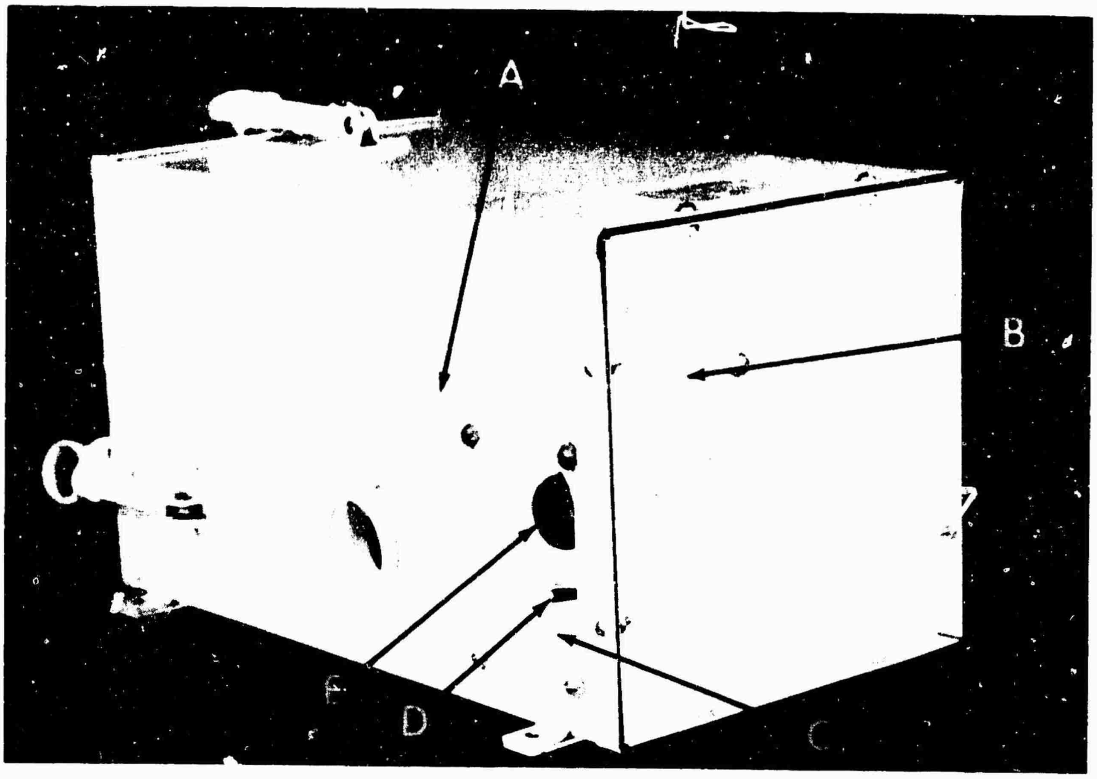

Figure 98. Protector, Facepiece, E21R2
(rear view)

A. Housing; B. dust deflector; C. switch cup; D. switch; and E. connector.

Figure 99. Blower-Precleaner Assembly, Facepiece Protector, E21R1

Figure 100. Motor-Blower Unit of Protector, Facepiece, E21R2

A. Mounting plate; H. precleaner; M. blower housing; N. cover plate; O. cover-plate screws; P. impeller; and Q. impeller-hub nut.

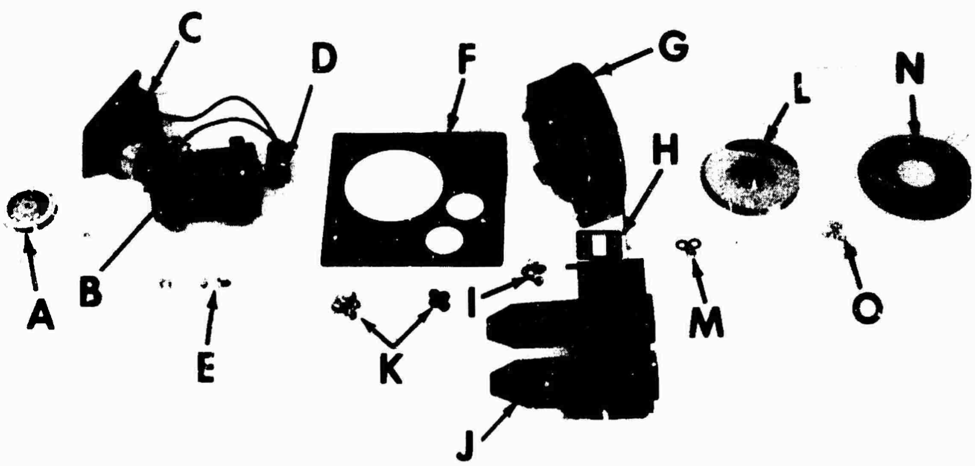

Figure 101. Motor-Precleaner Assembly, Facepiece Protector, E21R1, Disassembled

A. Motor-cooling fan and hub nut; B. motor; C. switch cup; D. condenser; E. motor-mounting screws; F. mounting plate; G. blower housing; H. precleaner gasket; I. precleaner mounting screws; J. precleaner; K. blower and precleaner mounting screws and nuts; L. blower impeller; M. impeller spacers and hub nut; N. blower cover plate; and O. cover plate screws.

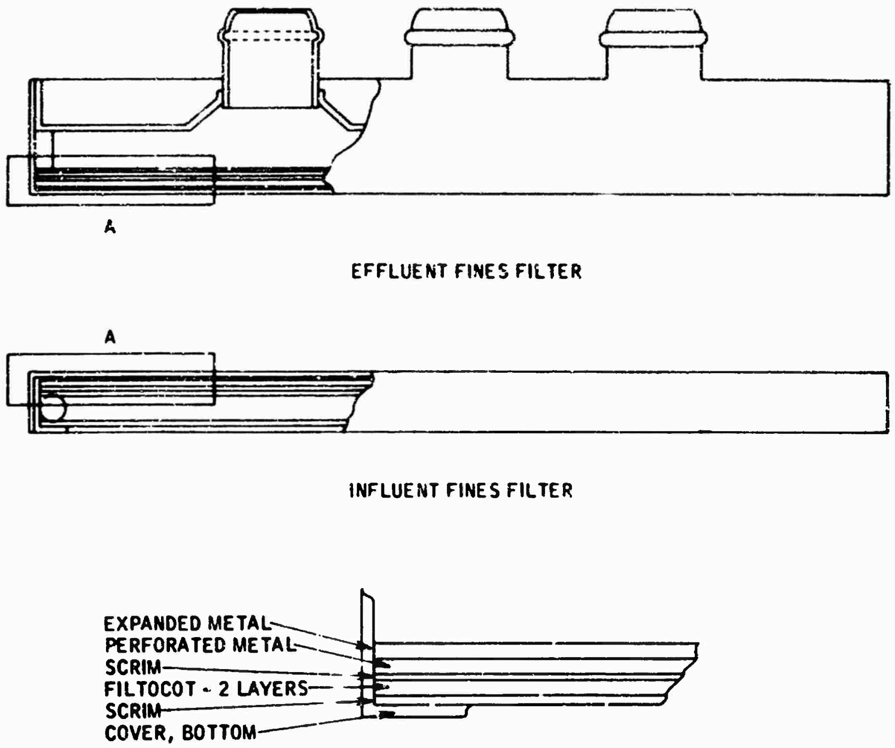

Figure 102. Drawing of Effluent and Influent Fines Filter

Figure 103. Various Assemblies Constituting One Three-Man Facepiece Protector, E22, of the Protector, Facepiece, E21R3

A. Air purifier assembly; B. inlet assembly; C. cable assembly; D. hose assembly; E. facepiece assembly; and F. facepiece carrier assembly.

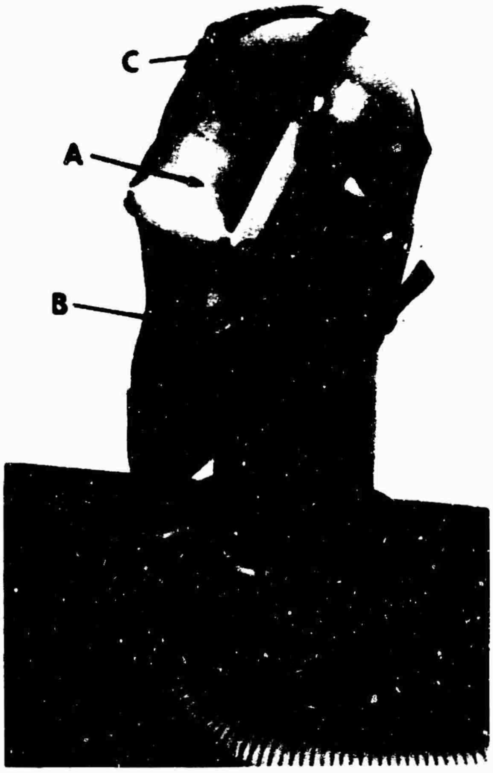

Figure 104. Facepiece Protector Mounted on a Dummy Head

A. Flexible rubber covered stockinette; B. eyepiece; and C. head harness.

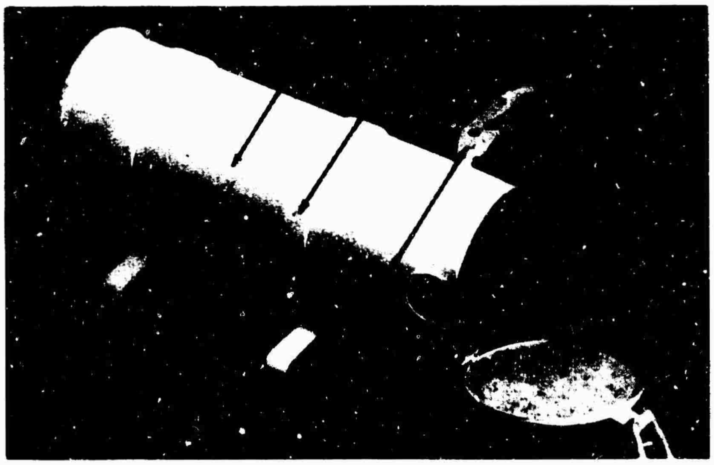

Figure 105. Facepiece Carrier Assembly-Protector, Facepiece, E21R2

A. Container; B. mounting clamps; C. cover; D. hinge assembly; and E. latch assembly.

h. Facepiece Protector, E22R1.

This protector consisted of one-half of an E21R4 unit.[80]

i. Six-Man Hospital Gas Protector, E23.

This Facepiece Protector was designed for use in hospitals to furnish purified air to patients with head-wounds. One E22R1 unit with a transformer, head-wound masks, additional hoses, Y-tubes, etc., constitute the E23 unit. Figure 106 shows a sketch of an installation. Only half the quantity of air supplied per man in a tank was deemed necessary for hospital patients. Figure 107 shows a photograph of the protector in use. A closeup of a mounted head-wound mask is shown in figure 108.[30]

4. Canisters for the Facepiece Protector.

a. E5 Canister.

The E5 Canister consisted of three M1 Horse-Mask Canisters in an outer body.

b. E5R1 Canister.

Six M10A1 Canisters less nozzles, screwed into the cover of an outer body, comprised the E5R1 Canister.

c. E5R2 Canister.

Six M10A1 Canisters placed on a 1-in. deep plenum and held by straps and through bolts made up this canister.

d. E5R3 Canister.

The E5R3 Canister was built of six M11 canisters mounted in a suitable container.

e. E5R4 Canister.

Six M10 or M10A1 Canisters mounted in a container made up the E5R4 Canister.

f. E6 Canister.

This was a cylindrical unit with axial flow, 9 in. in diameter with a 2-in. deep charcoal bed, and a shell (type II) pleated filter.

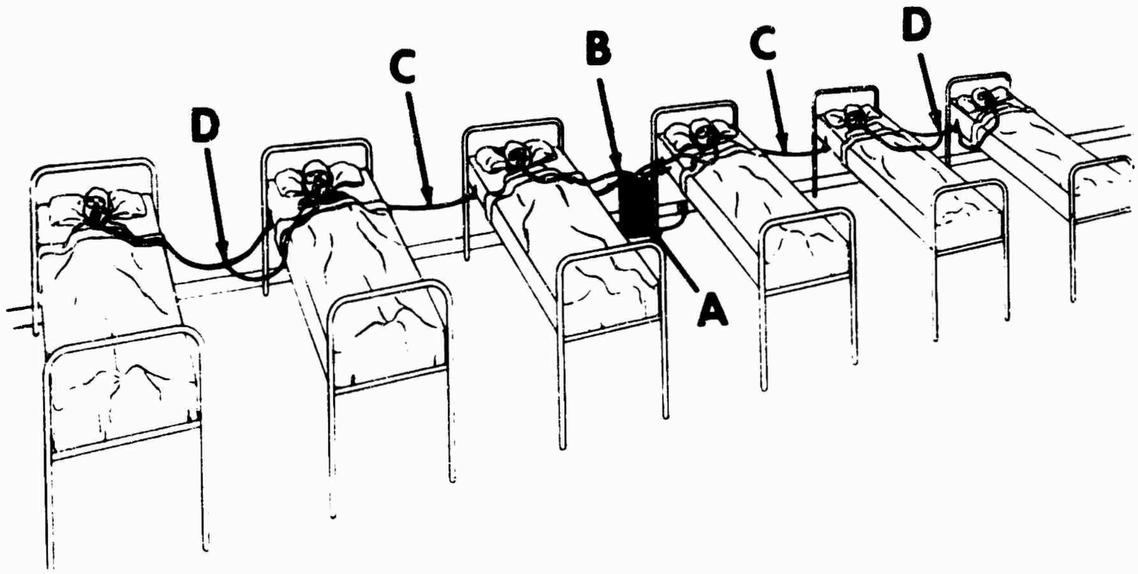

Figure 106. Gas Protector, Hospital, Six-Bed Assembly

A. Air purifier unit; B. hoses from canister Y tube; C. longer hoses; D. Y tubes dividing air for two beds.

Figure 107. Pressurized Headwound Mask

A. Air purifier; and B. hoses connected from Y tube to facepieces worn by the patients.

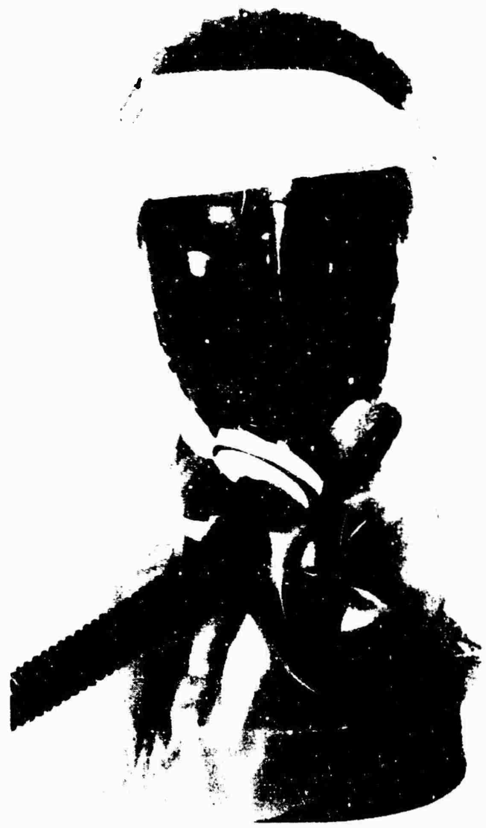

Figure 108. Pressurized Headwound Mask on Dummy Head

g. E6R1 Canister.

This canister was 7-7/8 in. square by 4-5/16 in. deep with the shell-type pleated paper filter and a 2-in. deep charcoal bed (2100 ml) of 12 to 30 mesh ASC charcoal.

h. E6R2 Canister.

The dimensions of this can were 7-7/8 by 7-7/8 by 5-1/4 in. It had a 7-5/8 in. diameter shell-type filter and a 2-in. deep charcoal bed. It differed from the E6R1 canister in the method of assembling the metal parts.

i. E6R3 Canister.

This canister design was arrived at after a conference with the Stacklerin Corporation. Figure 35 shows the parts and construction of this can.

j. E7 Canisters.

This canister was 8-in. square by 4-in. deep and had as a smoke filter a 1-in. thick pad of asbestos wool.

k. E7R1 Canister.

This canister had the 1-in. thick asbestos-wool filter in a separate package from the charcoal layer so that it could be replaced.

5. Tests of Facepiece Protector.

a. The E21-type Facepiece Protector was installed in an M4A1 tank and tested with SO_2, CG, CC, OH, and CN. No gas penetrated into the tank.

Dust tests were run by driving the tank behind a lead vehicle over a standardized dust course for a distance of 36 miles. At the close of the test the engine air cleaners were sufficiently loaded with dust to require clearing, but no appreciable decrease in airflow output of the air purifier was observed.[81]

b. The Facepiece Protector in an M4A1 tank was tested from a physiological viewpoint by the Armored Medical Research Laboratory and compared with the combat mask and a collective protector for a T23 tank.

Although the men preferred the Facepiece Protector from a comfort viewpoint when the airflow was reduced to 3.5 cu ft/min, the conclusion reached was that there was not enough advantage over the combat mask to warrant its adoption.*

c. The E21R2 Facepiece Protector was tested under actual combat conditions in the Pacific Theater. The units were installed in medium tanks in three different tank battalions on the 13th Armored Group, 6th Army. No difficulty was experienced in the installation and no necessary equipment was replaced. In all, nine installations were made.

After 2 to 4 weeks of experience with the units the tank crews were interviewed and their opinions were compiled. They felt that although they would hesitate to install the protector in anticipation of gas warfare, the equipment, which could be satisfactorily stowed with no displacement of essential items and so that it is out of the way, provided needed protection from gas fumes and dust.

On the basis of these tests the recommendation was made that the E21R2 Facepiece Protector be installed in all tanks.[82]

*Final Report on Project No. 35 op cit.

d. The Canadians, who first developed a facepiece protector, have conducted several field trials of the equipment and found that it gave protection against gun fumes and nonpersistent chemical warfare agents.*,[83]

One test made by the Canadians which compared the American Facepiece Protector with the Canadian unit showed that the American unit delivered air to the facepiece at a temperature several degrees below that of the Canadian unit.**

J. Gas Protection of Oxygen Generators.

1. Military Requirement.

There was a military requirement by the Army Air Corps for this equipment.

2. Military Characteristics.

No approved military characteristics were written.

3. Models of the Air Purifiers for Use With Oxygen Generators.

a. Air Purifiers, Oxygen Generator, MITE1.

Figure 109 shows the MITE1 Oxygen Generator Air Purifier. One part of the unit shown in solid lines in the sketch, comprised a standard M1 Air-Purifier Tube (CWS Drawing B5-23-56). Those parts shown dotted, were added to the standard tube to adapt it to the compressor inlets of the oxygen generator and to protect it from the weather. The standard tube was filled with Grade II ASC impregnated charcoal and wrapped with Type 4 asbestos-impregnated filter material. A brass adapter machined to a standard 3/4-in. pipe nipple was soldered to the outlet flange of the air-purifier tube. A sheet-metal housing, which completely surrounded the tube, was soldered to this coupling and to the end plate of the tube. The ends of this housing consisted of metal discs having a ring of 1/2-in. holes near the outer edge to permit entrance of air into the annular space between the air-purifier tube and the housing. A sheet-metal cover was mounted on the closed end of the tube to prevent entrance of rain water into the unit. Twenty tubes of this design were constructed and subjected to a field test on an O_2A Oxygen Generator at Wright Field.

The brass mounting nipple failed on gas tests because leaks developed. Further development was therefore directed at improving the nipple design.

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*Chemical Warfare Laboratories (Canada). Air Filtration Unit. Trials of Chemical Attack Against Protected M4A4 Tanks. October 1943.

**A Comparison of the Canadian and American Systems of Air Filtration for AFV Crews Under Moderately High Temperature Conditions. 15 December 1944.

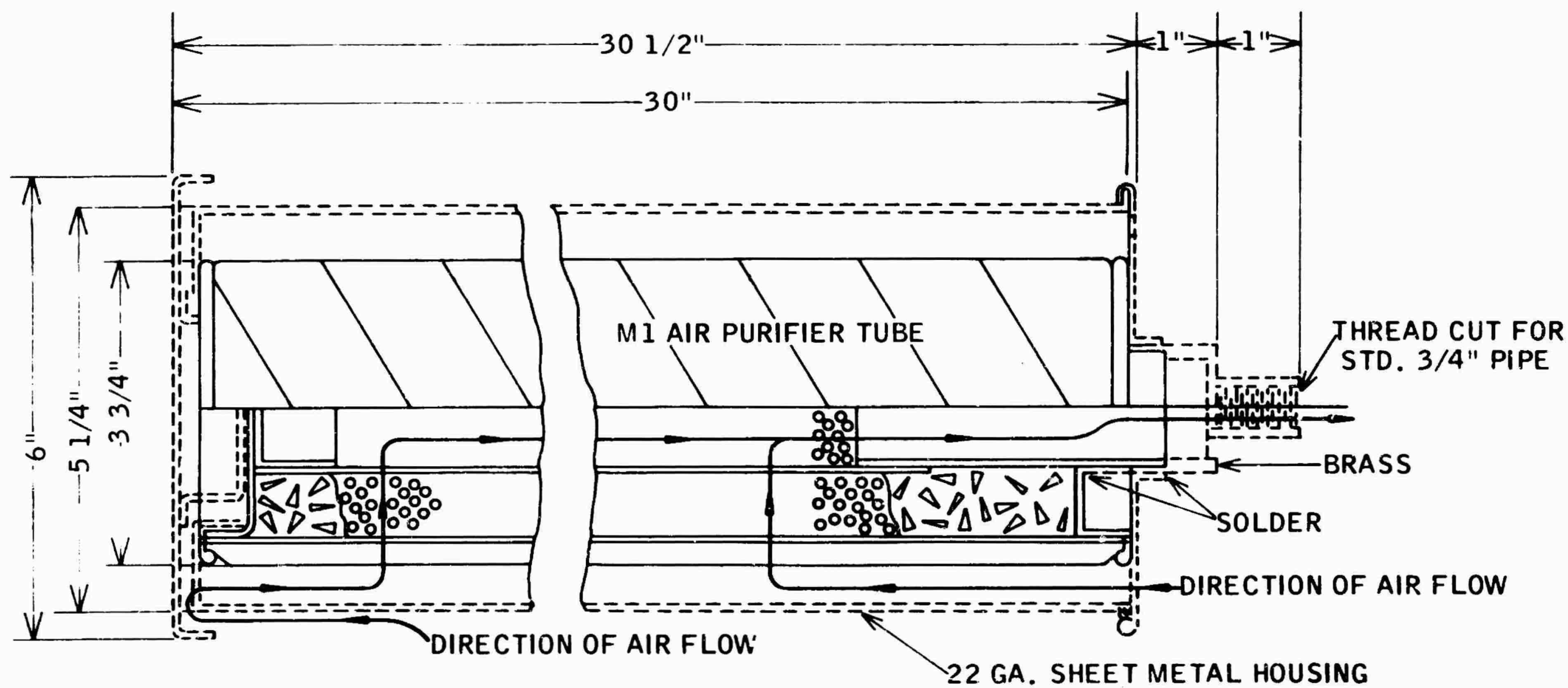


Figure 109. Air Purifier, Oxygen Generator MITE1

b. Air Purifier, Oxygen Generator, MITE1R1.

Figure 110 shows this model. The standard 4-in. long inner-tube extension for the M1 Air-Purifier Tube was replaced with a heavier tube having a wall thickness inside the air purifier approximately twice that of the standard inner-tube extension. This tube was brazed into a heavy brass adapter, threaded for 1-1/2-in. pipe. These air-purifier tubes were filled and wrapped in the normal manner making whatever changes were necessary in the jigs and fixtures on the filling apparatus.

c. Air Purifier, Oxygen Generator, MITE1R2.

This air purifier consisted of a standard M1 Air-Purifier Tube enclosed in a housing similar to that used with the MITE1R1. A brass fitting for a flexible-metal duct, which consisted of an 8-in. length of flexible metal tubing with a single brass braid (American Brass Company) was soldered on the standard inner-tube extension and outlet nipple. This was connected by a union connector to the compressor inlet. On the opposite end of the air-purifier housing was welded a small metal loop to suspend the tube from the trailer roof. An eye bolt and short length of chain were required to mount this air purifier.

d. Air Purifier, Oxygen Generator, MITE1R3.

This unit was similar to the MITE1R2 except that a short length of rubber duct was used instead of the flexible metal tubing.[84]

4. Tests of Oxygen Generator.

The MITE1 Air Purifier was tested by mounting on an O_2A Oxygen Generator. The generator was then operated normally and in an atmosphere containing 0.8 mg/l of CG for 12 hours.

Each protected inlet handled 10.4 cu ft/min of air. Since the M1 Air-Purifier Tube was rated at 12.5 cu ft/min, modification of these tubes for use on each inlet was considered feasible. This was borne out by the five MITE1 Air Purifiers which did not fail mechanically at the mounting nipple since they gave complete protection for the duration of the phosgene test.

The addition of the tubes to the oxygen generator installation caused no decrease in the oxygen production.

Later models, the MITE1R1, E1R2, and E1R3, were subjected to a 2-month mechanical endurance test under continuous operation of the generator. At the end of this period the Army Air Corps chose the MITE1R2 model as the most desirable.[84]

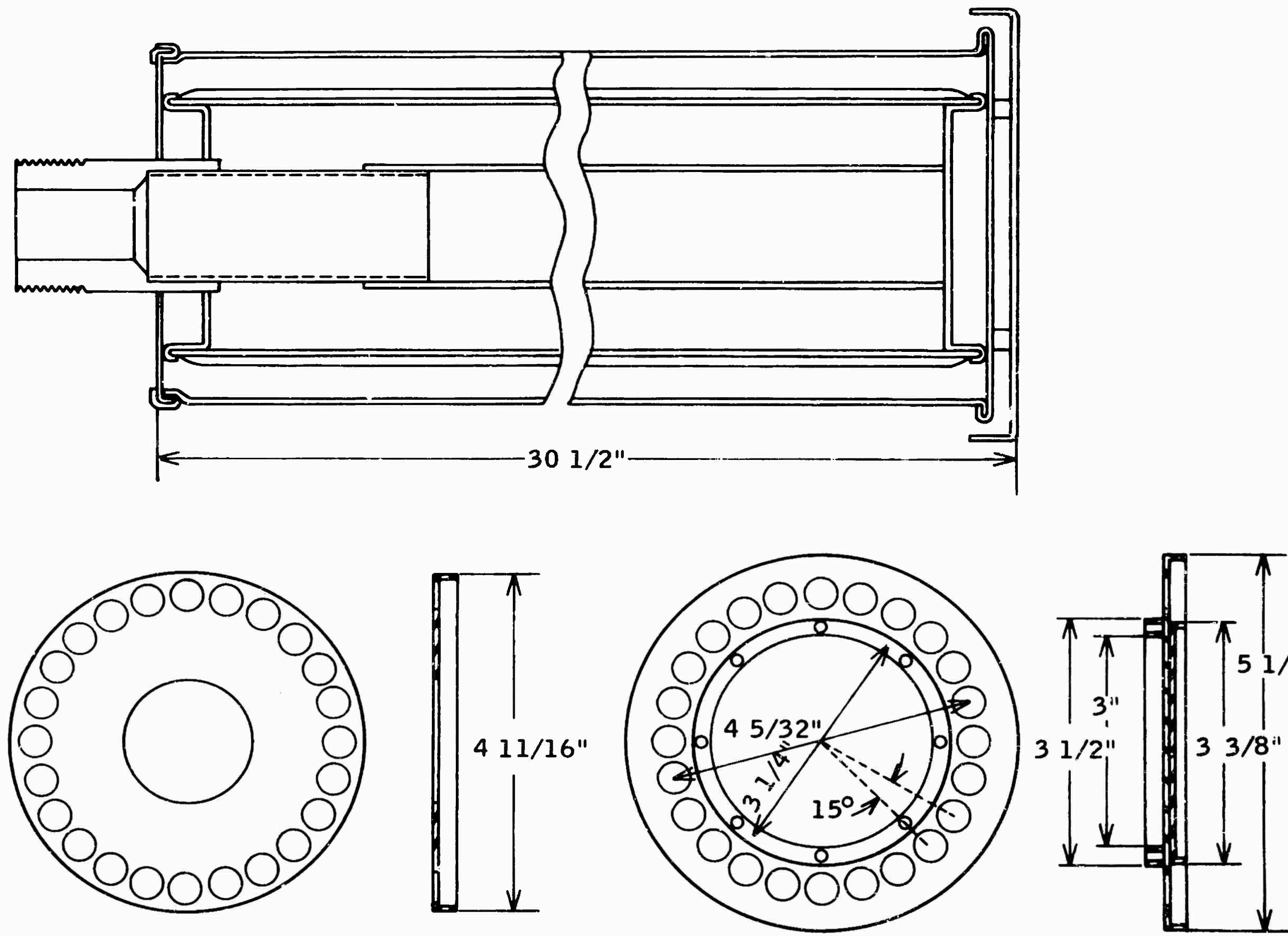


Figure 110. Air Purifier, Oxygen Generator MITE1R1

K. Collective Protector Canister Dehumidifier.

1. Military Requirement.

There was a military requirement for an apparatus to be used for the drying collective protector canister in permanent and field installation. A formal military requirement was established concurrent with the writing of military characteristics.[85,86]

2. Military Characteristics.

(a) The dehumidifying apparatus should be compact, simple in operation, rugged in construction, and light in weight.

(b) The apparatus should be capable of being carried in a truck over rough terrain.

(c) The apparatus should be so constructed that it can be carried readily by not more than two men.

(d) The apparatus should be designed for use in drying canisters of collective protection equipment installed in permanent structures as well as for the drying canisters of field-installed collective protectors.

(e) The apparatus should be gasoline-engine driven or otherwise designed so that it will be independent of a source of electric power or heat for operation.[85,86]

3. Models of the Canister Dehumidifier.

a. Apparatus, Drying, Canister, MITE1.

It was found that if air of any naturally-occurring relative humidity were heated to 180°F the relative humidity of the air would drop to a level low enough to serve as an efficient drier of collective protector canisters. The principle of heating the air to this level was used in the design of all the dehumidifiers.

The MITE1 model was a laboratory, experimental unit, consisting of a sheet-metal pipe filled with electrical strip heaters. Figures 111 and 112 show photographs of this unit.[45]

b. Apparatus, Drying, Canister, MITE2.

This drier, shown in figures 113, 114, and 115 was modelled after the M2A2 collective protector and consisted of the following parts:

(1) A gasoline, model I, Briggs and Stratton engine, used to drive the blower.

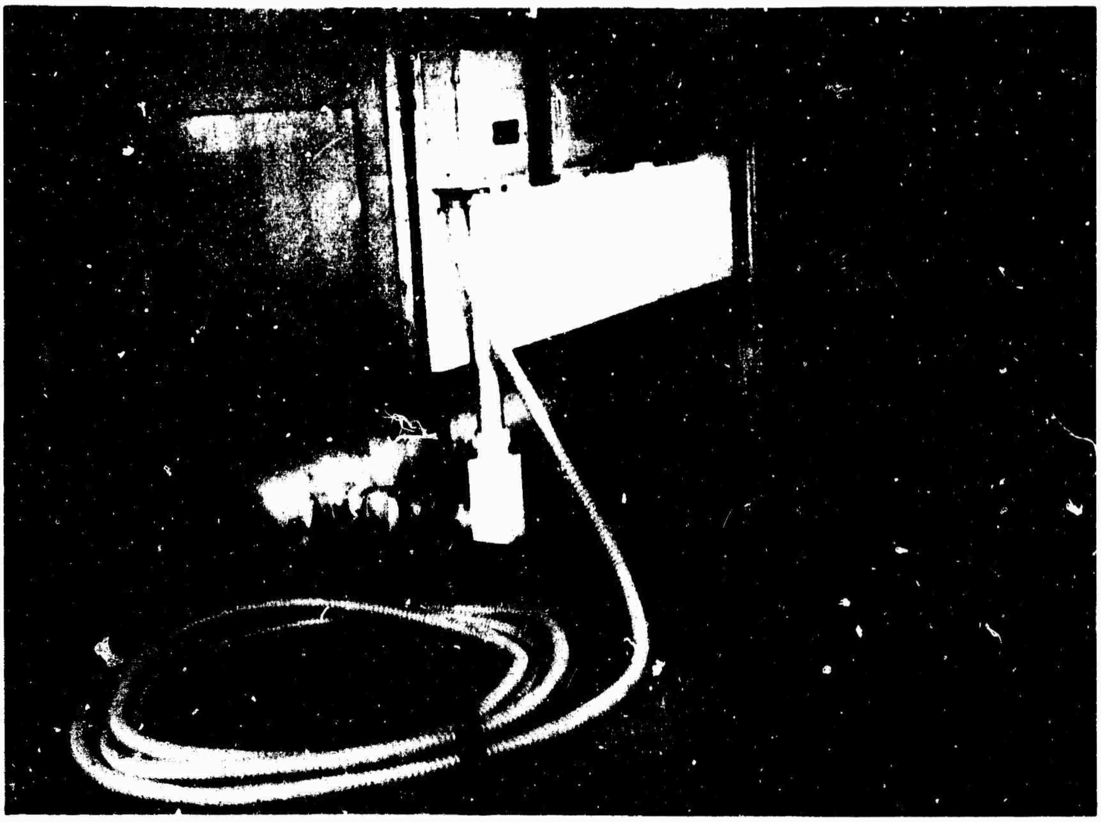


Figure 111. Canister Dehumidification Heater
(experimental)

(2) A gasoline heater, "Hunter and Co. OH-32," which was mounted at the blower inlet.

(3) An Autolite GCZ 4801 automobile generator, connected by a belt to the gas engine and generating 6.5 to 7 volts for operation of the ignition and the combustion air fan of the gasoline heater.

(4) A cradle for supporting the canister.

(5) A quick-acting, clamping arrangement for holding the canister tight against blower discharge.

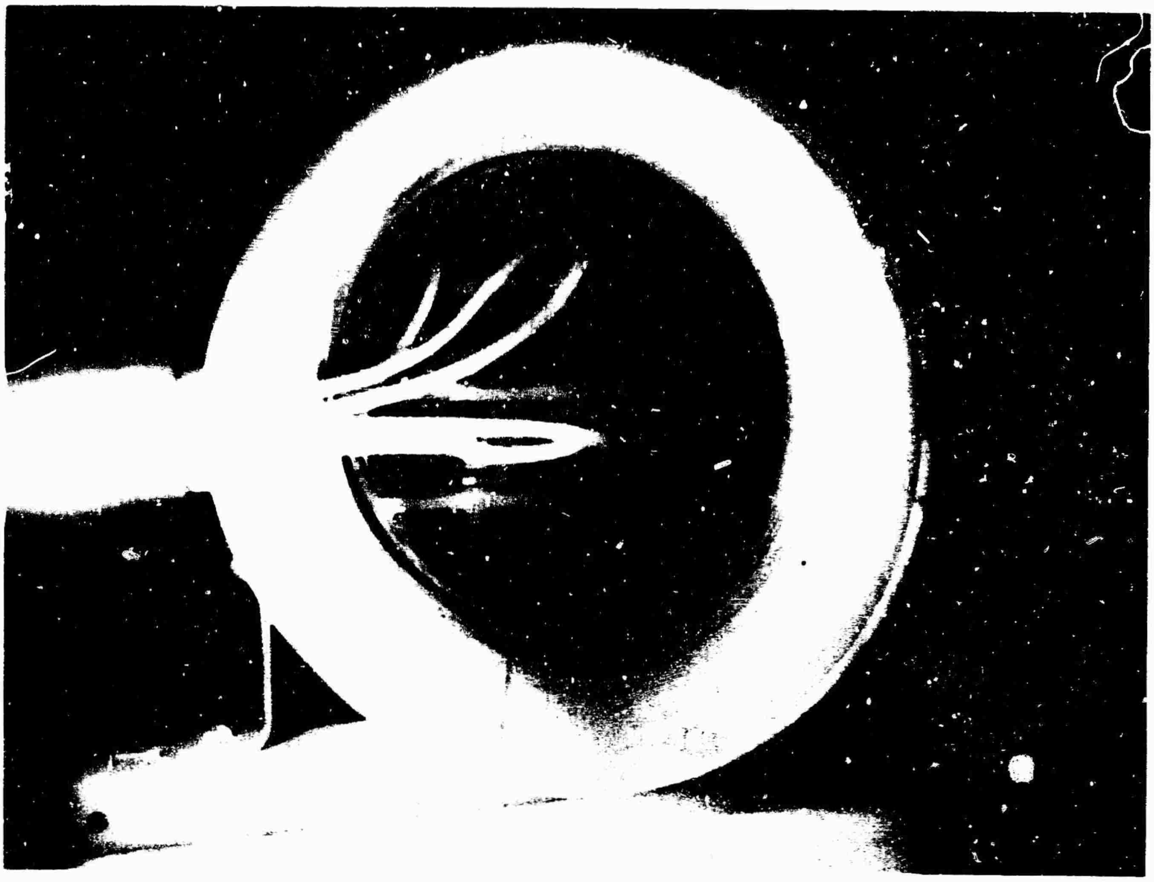


Figure 112. Canister Dehumidification Heater
(end view)

c. Apparatus, Drying, Canister, MITE3 (Final Model).

Figures 30 and 116 show the essential parts of the MITE3 Canister Drying Apparatus, assembled for dehumidifying an M1 Collective Protector Canister.

The apparatus consisted of a gasoline-engine-driven blower which drew air through a Hunter heater and blew it through the canister. An electric generator supplied power for the heater. The motor-blower and generator were mounted on a frame for ease in handling. Flexible, corrugated tubing was used to connect the various components. Sandbags placed on the blower frame kept it from "walking."[46]

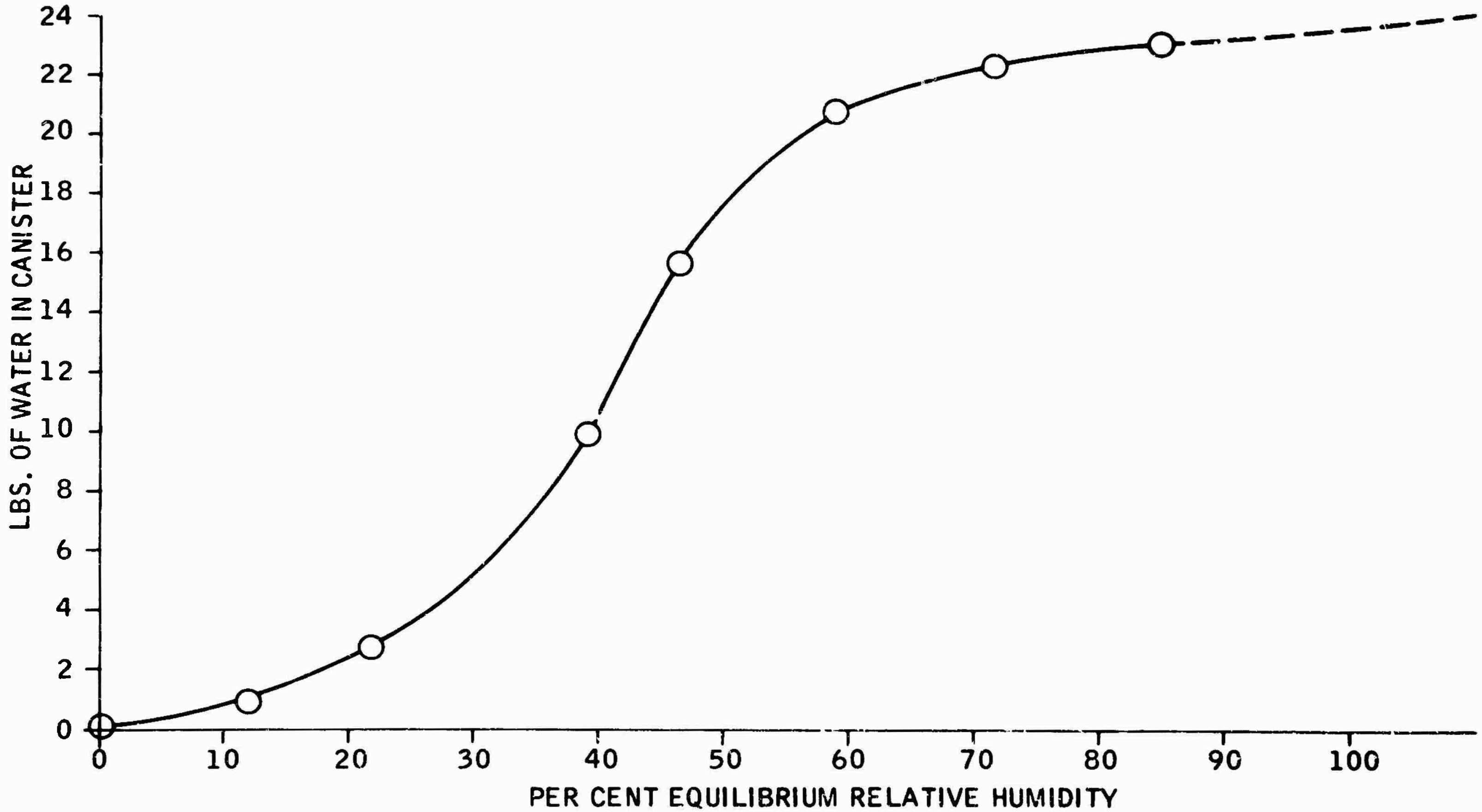


Figure 113. Equilibrium Relative Humidity vs. Moisture Content
M1CP Canister Ser. No. 998. Lot No. 3338-1
Type A Charcoal, IAW Filter

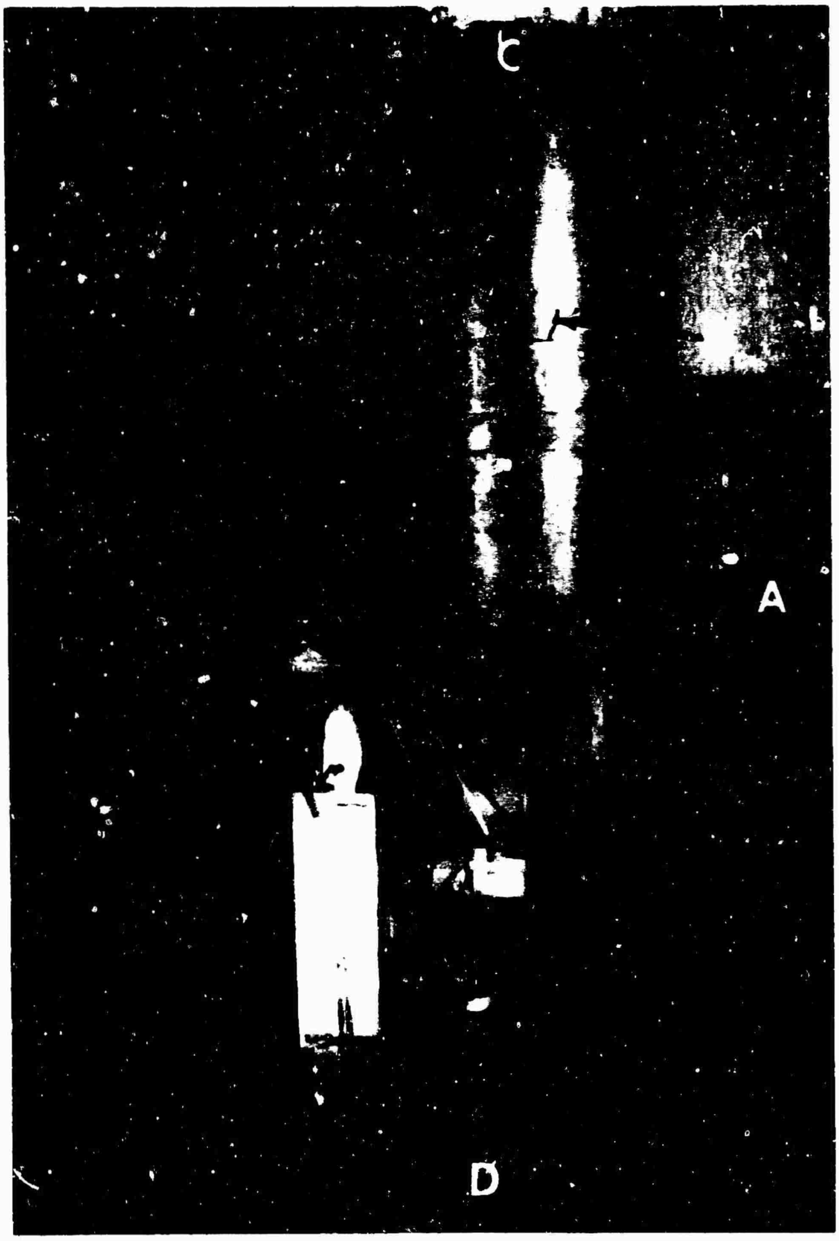
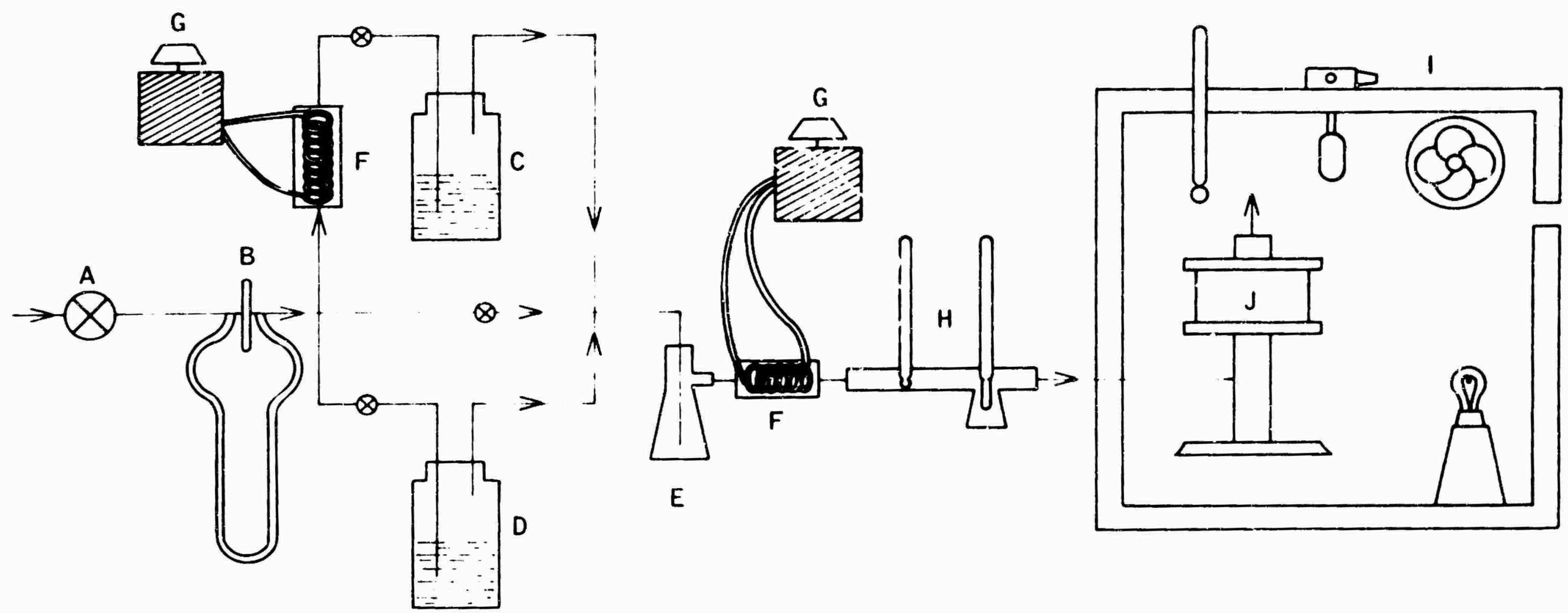


Figure 114. Equilibrium Humidity Test

A. M2 collective protector; B. M1 canister; C. nipple inserted in hole drilled in canister; and D. humidity test meter (experimental).



A - AIR-PRESSURE REGULATOR
B - ORIFICE AND MANOMETER
C - TWO-QUART MASON JAR HALF FILLED WITH WATER
D - TWO-QUART MASON JAR HALF FILLED WITH CONC. H_2SO_4
E - MIXING AND WATER SEPARATOR BOTTLE
F - DIRECT CONTACT - ELECTRICAL AIR HEATER
G - 5 AMPERE VARIACS TO CONTROL POWER INPUT TO HEATERS
H - WET-BULB AND DRY-BULB HOLDER FOR MEASURING AIR INLET HUMIDITY
I - CONSTANT TEMPERATURE BOX EQUIPPED WITH THERMOMETOR, THERMOSTATIC CONTROL, AIR-CIRCULATING FAN, AND 100 WATT BULB AS HEAT SOURCE.
J - 4 1/4" CAN CONTAINING CHARCOAL BED, AS CLAMPED IN CAN HOLDER

Figure 115. Equipment Used to Study the Rate of Humidification in Minicans

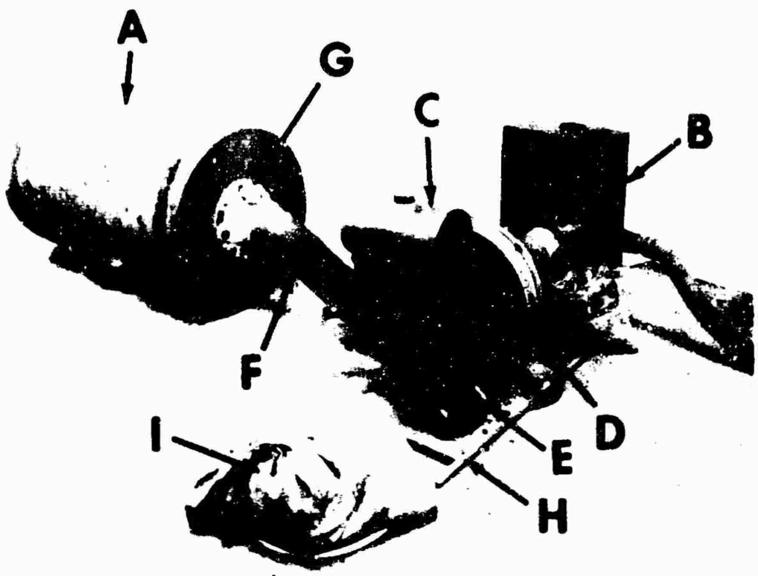


Figure 116. Canister Drier MITE3

A. M1 collective protector canister; B. gasoline heater; C. gasoline engine; D. blower; E. electric generator (to supply electric power for heater); F. connection tubes; G. thermometer (for air entering canister); H. supporting frame; and I. sandbags.

d. Field Drying Expedient.

In the absence of a drying appartus field expedient methods of drying were developed. The apparatus consisted of a bundle of iron pipes heated by burner units from two M1937 Field Ranges or by four blow torches through which air was drawn and passed through the canister mounted on an M2A2 Collective Protector. Figures 117 and 118 show the field expedient equipment.[46]

4. Models of the Humidity Test Meter.

a. General.

To determine when it was necessary to dehumidify a collective protector canister, it was necessary to determine when the moisture content of the charcoal had reached an unsafe level. It was found that the relative humidity of the air in a collective protector canister was a measure of the moisture content of the charcoal.[45]

Figure 117. Collective Protector Canister Dryer Showing Location
of Thermometer for Air Temperatures

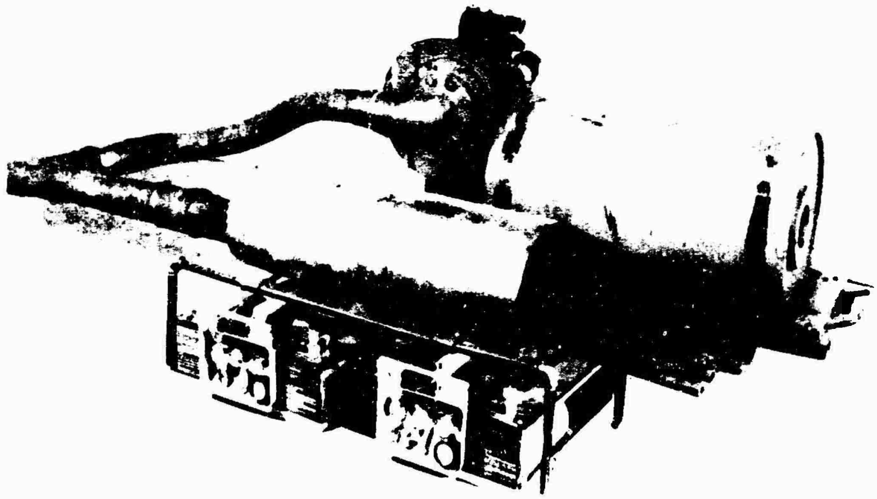


Figure 118. Collective Protector Canister Dryer Showing Complete Setup

b. Humidity Test Meter, MITE1.

This test meter consisted of an electric motor and air pump and a wet- and dry-bulb psychometer. Air was sucked through the canister, over the wet- and dry-bulb psychometer, and through an orifice to control the flow. The unit was heavy (55 lb) and bulky for field use and could not be operated in localities devoid of electrical power. The performance of the unit was satisfactory. Figures 119 and 120 show the construction details of the tester.[46]

c. Humidity Test Meter, MITE1R1.

This test meter contained only a wet- and dry-bulb psychometer and a nozzle. It was intended for use only in the laboratory to test the principle of using the collective protector blower to force air through the collective protector canister and over the wet- and dry-bulb arrangement. The case was constructed of wood. This test meter performed satisfactorily, but was not rugged enough for field use. Figure 121 shows this unit.

d. Humidity Test Meter, MITE1R2.

This test meter was identical with the MITE1 model except that a case of 18 gage sheet metal and brass was substituted for the wood case as shown in figure 122.[46]

The method of test consisted of (1) drilling a hole in the cover plate of the canister, (2) tapping this hole and inserting a 1/8-in. pipe nipple, (3) closing the discharge valve from the collective protector canister, (4) opening the inlet valve to the canister, (5) connecting the test meter to the nipple by means of a 7-ft length of 1/2-in. inside diameter rubber tubing, (6) starting the collective protector blower and regulating the airflow through the test meter to the indicated value by adjustment of the valve, (7) reading the wet and dry bulb temperature, and (8) determining the serviceability of the canister by reference to the graphs enclosed with the test meter.[46]

e. Humidity Test Meter, MITE1R3.

This meter consisted of a metal carrying case with a wet-and dry-bulb psychometer, an orifice-type flowmeter with a liquid manometer, and a small motor and blower. Its operation principle was similar to the final model MITE1R5 and it performed satisfactorily. Poor arrangement of the components in the carrying case necessitated removal of the thermometers and storing them in a special padded compartment to close the cabinet. The liquid manometer was also unsatisfactory for two reasons: (1) the liquid was easily spilled or bubbles were formed in the column when the meter was transported, and (2) if the airflow became too great, the liquid was blown from the manometer.[46]

f. Humidity Test Meter, MITE1R4.

A photograph of this tester is shown in figure 123. This model was very similar to the final model MITE1R5, but differed in that it had a somewhat larger and uninsulated

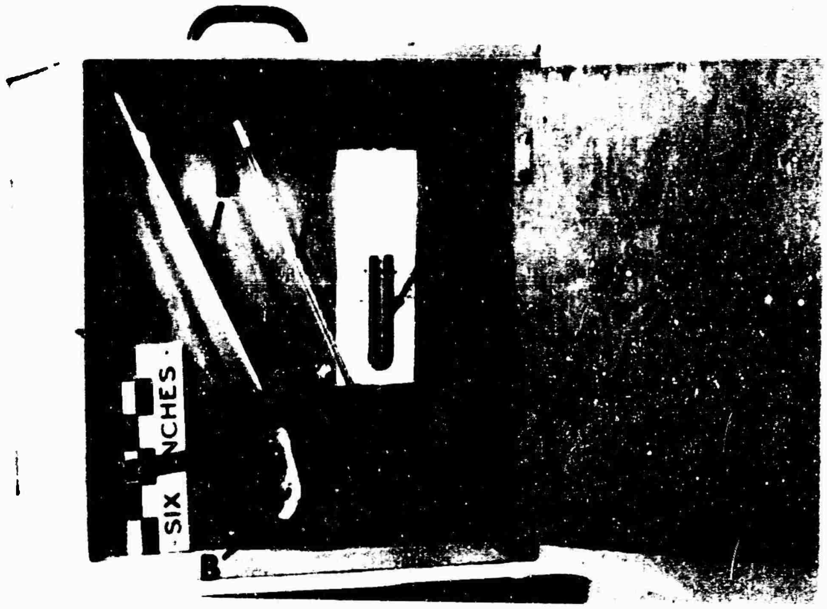


Figure 119. Open Front View of the El Humidity Test Meter

A. Nipple (for hose attachment to canister); B. psychrometer tube (glass); C. dry bulb thermometer; D. wet bulb thermometer; E. manometer; and F. angle iron and wood carrying case.

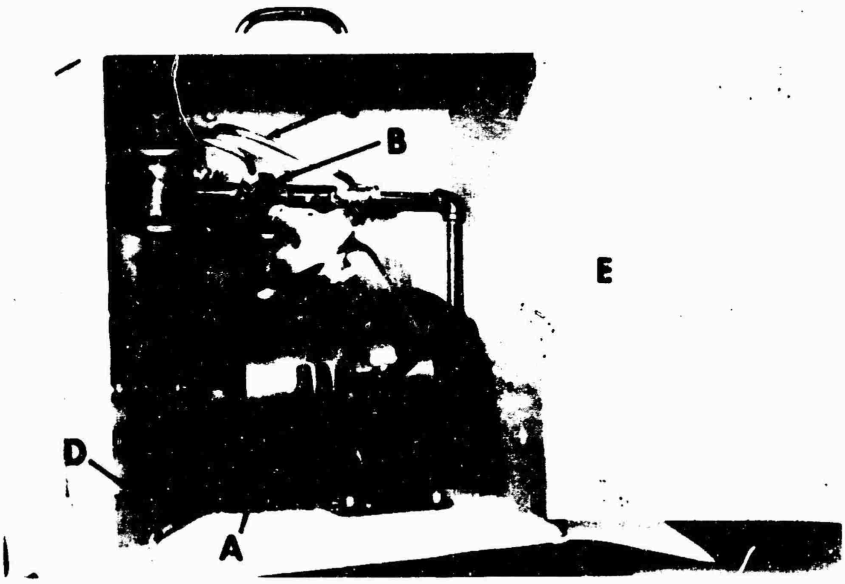


Figure 120. Open Rear View of the El Humidity Test Meter

A. Electric suction pump; B. orifice; C. manometer leads; D. electric cable; and E. carrying case.

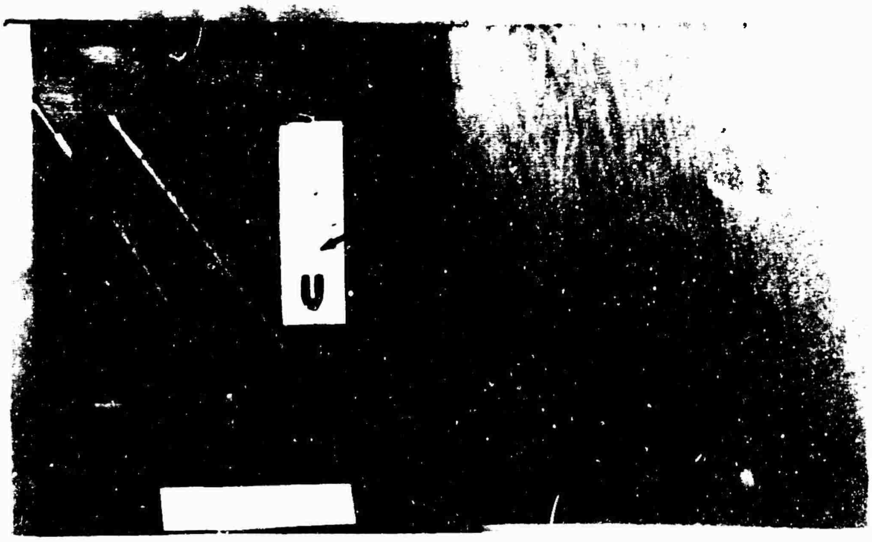


Figure 121. Open Front View of the E1R1 Humidity Test Meter

A. Psychrometer tube (glass); B. dry bulb thermometer; C. wet bulb thermometer; D. nozzle meter; E. manometer; and F. carrying case (wood).

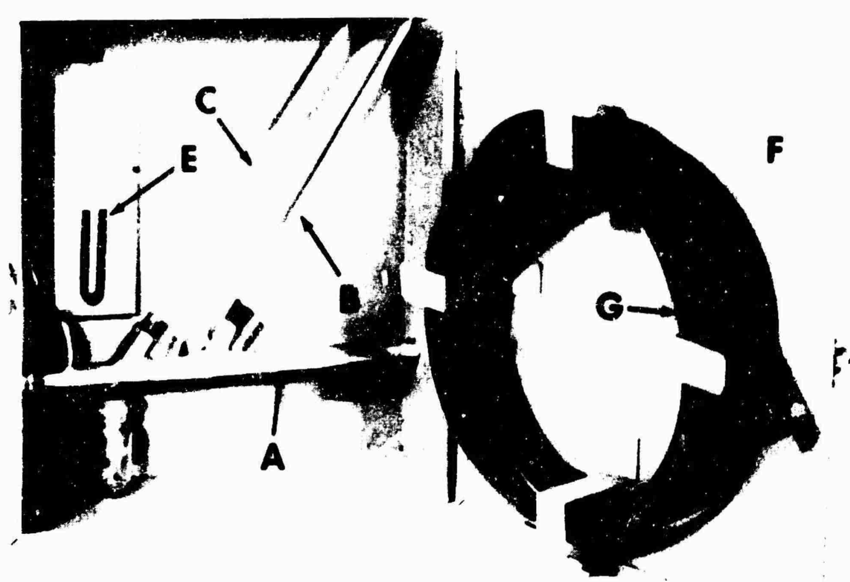


Figure 122. Open Front View of the E1R2 Humidity Test Meter

A. Psychrometer tube (brass); B. dry bulb thermometer; C. wet bulb thermometer; D. Nozzle meter; E. manometer; F. carrying case (metal); and G. hose.

psychometer tube, the transformer was mounted in the floor of the cabinet instead of on the blower bracket, and the hose storage was on the side of the cabinet. This model gave slightly erroneous readings because there was no insulation on the psychometer tube; this permitted heat emitted by the motor to affect the readings. Also this unit was more difficult to disassemble than the final model.[46]

g. Humidity Test Meter, MITE1R5 (Final Mode ,.

This h ımidity-test meter is shown in figure 124. The wet and dry bulb thermometers weıe mounted in an insulated tube through which air from the canister was drawn. A valve and a dry, ball-type flowmeter were used to regulate the airflow to 1.8 to 2.0 cu ft/min. A small motor blower which operated either from a 6-volt storage battery, or from a 110-volt ac line, drew the air from the canister through the test unit. The entire assembly was mounted in a sheet-metal box measuring 14 by 13 by 6-1/2 in., equipped with a carrying handle and with hooks to hang the tester on the edge of a vertically-mounted collective protector canister.

Additional components in the cabinet were: (1) serviceability charts to indicate whether the canister is or is not serviceable – these are based on a rejection limit of 55% equilibrium relative humidity; (2) a rubber tube and pipe fittings to conduct the air from the collective protective canister to the tester; (3) a jar of pipe dope and spare pipe plugs to repair the canister after test. The total weight of the apparatus was 26-1/2 lb.[46]

V. STANDARD ITEMS.

A. Protector, Collective, M1 (Limited Standard).

1. Military Requirement.

There was a military requirement for the M1 Collective Protector for use in fixed installation.

2. Description.

There were two types of the M1 Collective Protector; Type I was called right-hand, Type II was a mirror image of the former and was designated: left-hand.[33]

Weight (approximately)	1210 lb
Height	69½ in.
Width	22-3/4 in.
Length	95 in.

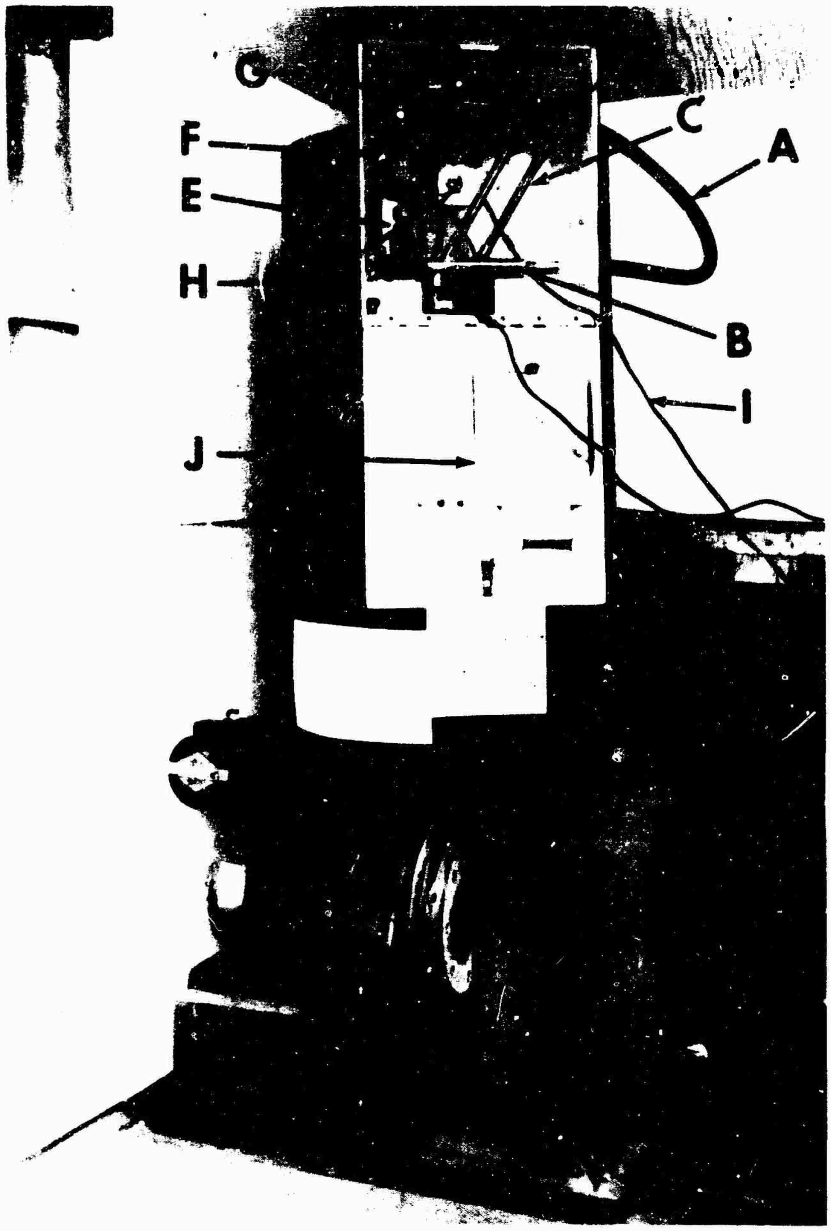


Figure 123. E1R4 Humidity Test Meter Mounted on a M2 Collective Protector

A. Hose (attached to psychrometer tube and to canister); B. psychrometer tube (brass); C. dry bulb thermometer; D. wet bulb thermometer; E. gate valve to regulate air flow; F. ball type rotameter; G. electric motor; H. electric switch; I. electric conductors; and J. humidity charts.

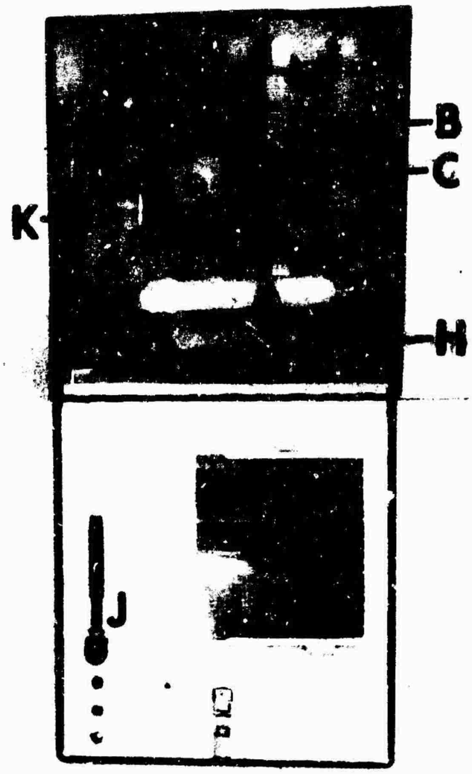


Figure 124. Meter, Humidity Test, E1R5

A. Psychrometer tube; B. dry bulb thermometer; C. wet bulb thermometer; D. gate valve (control air flow); E. ball type rotameter; F. electric blower, to be operated from 6 volt dc or (through transformer, K) from 110 volt ac; G. water bottle for wet bulb thermometer; H. connecting tube; I. serviceability charts; J. pipe fittings to connect psychrometer to canister; and K. transformer for 110 volt ac operation.

3. Operation.

Air was drawn from the inlet pipe by the blower through a tee and elbow to the canister where the air divided into streams which passed through 16 tubes which contained charcoal and were wrapped with filter paper. From the canister where the 16 purified air streams were combined into one, the air passed through a pipe elbow and from there through a second pipe tee. Between the canister and motor blower was a bypass line permitting air to bypass the canister by adjustment of a valve in the first tee after leaving the canister. The second tee, after leaving the canister permitted air to be supplied to an airblast outlet.

4. Packaging.

None.

5. Packing.

The protector is packed in four boxes containing (1) a canister, weighing 433 lb, boxed, and displacing 14.2 cu ft, (2) a blower and bypass, weighing 1080 lb, boxed, and displacing 66.8 cu ft, (3) an airblast outlet weighing 250 lb, boxed, and displacing 11.5 cu ft, and (4) miscellaneous items, displacing 5.02 cu ft.[33]

B. Protector, Collective, M1A2 (Standard).

1. Military Requirement.

There was a military requirement for the M1A2 Collective Protector for use in fixed installations.

2. Description.

The M1A2 Collective Protector was the same as the M1 except that it had no airblast feature.

3. Operation.

The operation of the M1A2 was the same as the M1 except for the airblast component.

4. Packaging.

None.

5. Packing.

Same as M1*,[60]

C. Protector, Collective, M2 (Limited Standard).

1. Military Requirement.

There was a military requirement for use of the M2 Collective Protector in semipermanent field installations; e.g., command posts and hospitals.

2. Description.

The M2 Collective Protector consisted of the same canister used on the M1 Collective Protector held in a vertical position by an appropriate supporting framework, and a gasoline engine connected to the blower. Figure 51 shows this unit. Twenty feet of flexible metal tubing was supplied with each unit.[33]

Weight (approximately)	650 lb
Height	65 in.
Width	31 in.
Length	31 in.

3. Operation.

Air was drawn through the canister and purified by the blower when driven by the gas engine.

4. Packaging.

None.

5. Packing.

The M2 Collective Protector was packed for shipping in two boxes containing: (1) a canister, weighing 433 lb, boxed, and displacing 14.2 cu ft, and (2) an engine, blower, tool box, and miscellaneous parts, weighing 483 lb, packed, and displacing 24.2 cu ft.[33]

*CWS Specification 197-54-339.

D. Protector, Collective, M2A1 (Limited Standard).

1. Military Requirement.

Same as for the M2.

2. Description.

Same as the M2 except that the M2A1 Collective Protector was powered by a 1/2-hp electric motor.

3. Operation.

Same as M2 Collective Protector.

4. Packaging.

None.

5. Packing.

Same as for M2 Collective Protector.

E. Protector, Collective, M2A2 (Standard).

1. Military Requirement.

Same as for M2 Collective Protector.

2. Description.

Same as M2 Collective Protector except that the canister was in a horizontal position.

Weight	615 lb
Length	64 in.
Width	25 in.
Height	32 in.

Figures 125, 126, and 127 show various views of this protector with its round M1 canister. Figure 128 shows the M2A2 Collective Protector with its square canister.

3. Operation.

Same as M2 Collective Protector.

4. Packaging.

None.

5. Packing.

The M2A2 Protector was either packed in one waterproofed box as a complete unit, or the canister could be removed and packed in a separate waterproofed box, the two boxes comprising the complete unit for shipment. The M1 Canister, crated, weighed 433 lb and displaced 14.2 cu ft. The square canister, crated, weighed 363 lb and displaced 11.09 cu ft. The entire unit (with M1 Canister installed) weighed about 900 lb and displaced 50.81 cu ft, when crated. Without the canister, the crated unit weighed about 600 lb. Figure 129 shows the M2A2 Collective Protector packed in a waterproofed box.

F. Canister, Collective Protector, M1.

1. Military Requirement.

There was a military requirement for a collective protector canister to be used as a replacement for collective protectors set up in military installations.

2. Description.

A picture of the M1 Canister mounted in position may be seen in the photograph of the M1, M2, and M2A2 Collective Protectors. It was a cylindrical can, 39-1/2-in. long by 21 in. in diameter, and weighed 314 lb.

3. Operation.

The canister contained 16 tubes of charcoal wrapped with filter material. Air entered one end of the canister and passed through the 16 tubes which were arranged in parallel. Purified air was drawn from the opposite end of the can.

4. Packaging.

None.

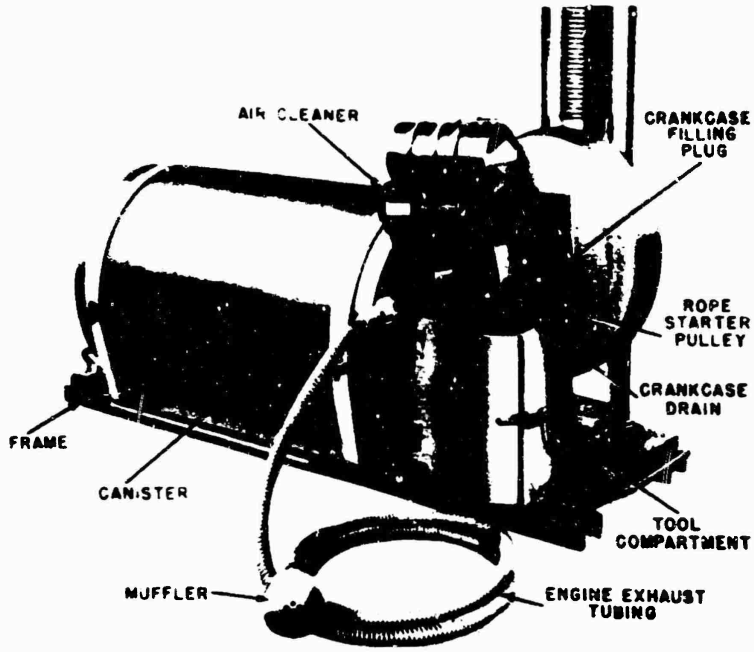


Figure 125. Collective Protector M2A2 Equipped with M1 Collective Protector Canister (tool compartment side)

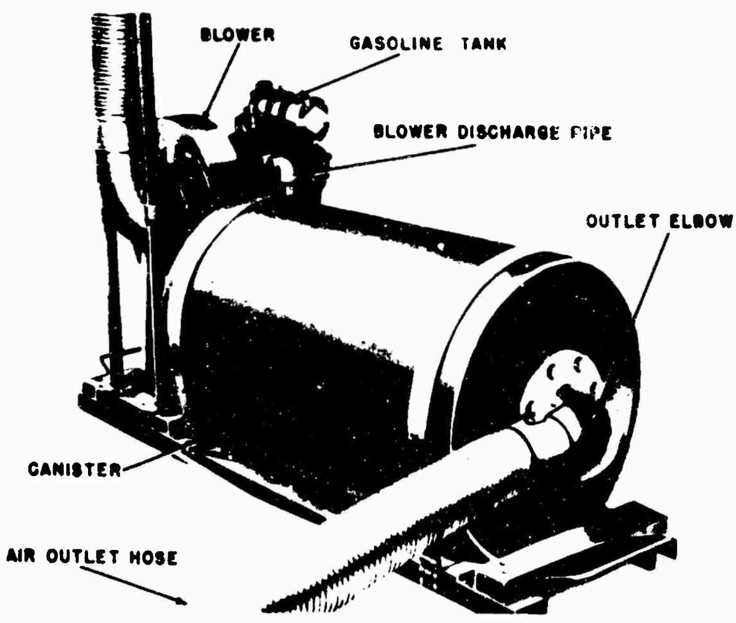


Figure 126. Collective Protector M2A2 Equipped with M1 Collective Protector Canister (air outlet side)

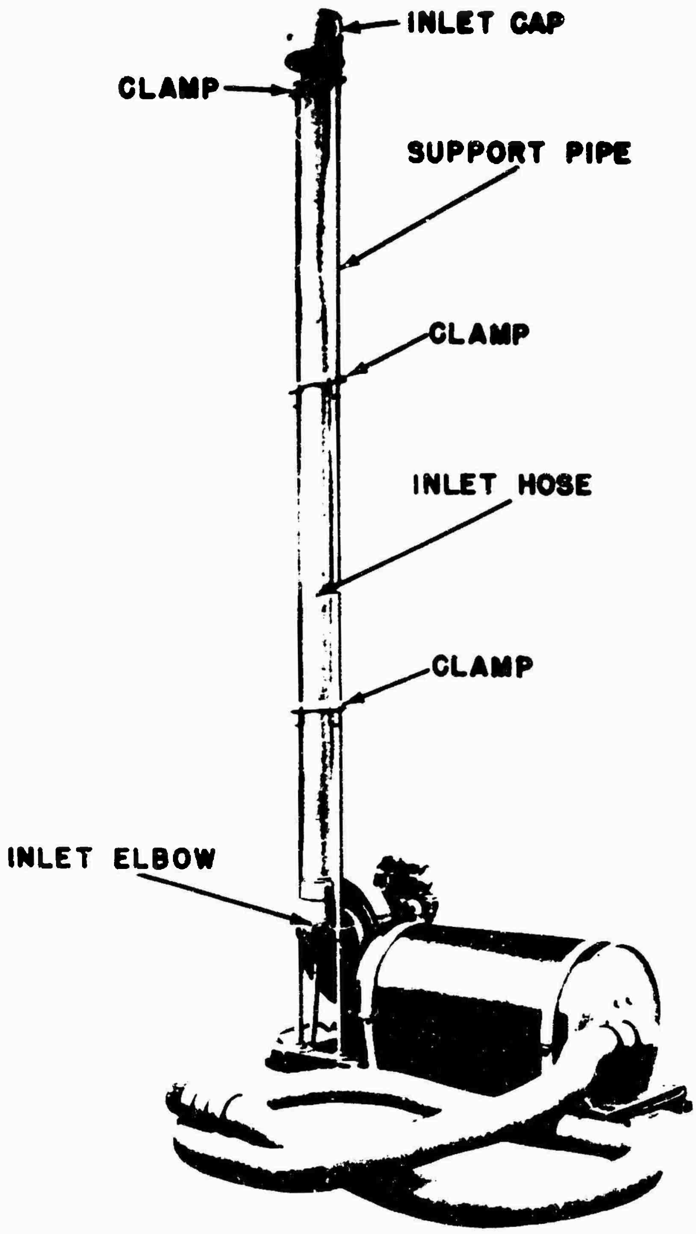


Figure 127. M2A2 Collective Protector Showing Inlet Equipment

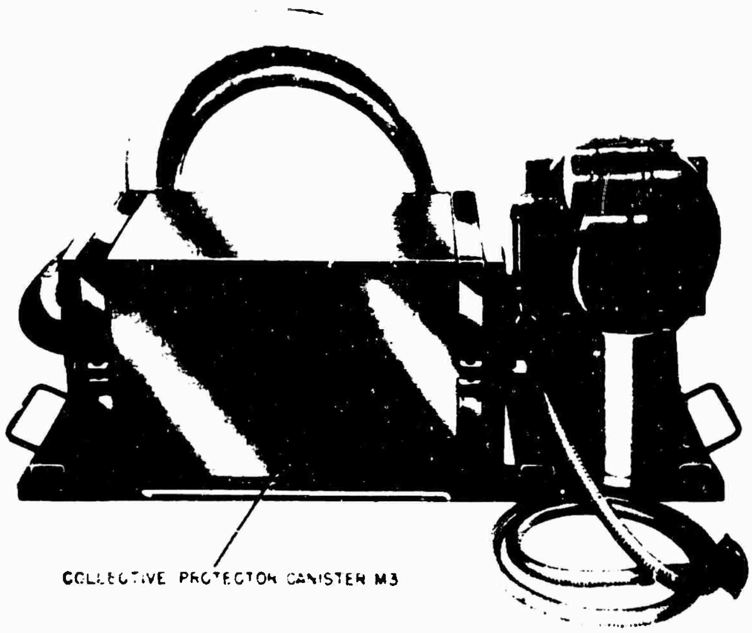


Figure 128. Collective Protector M2A2 Equipped with Collective Protector Canister M3

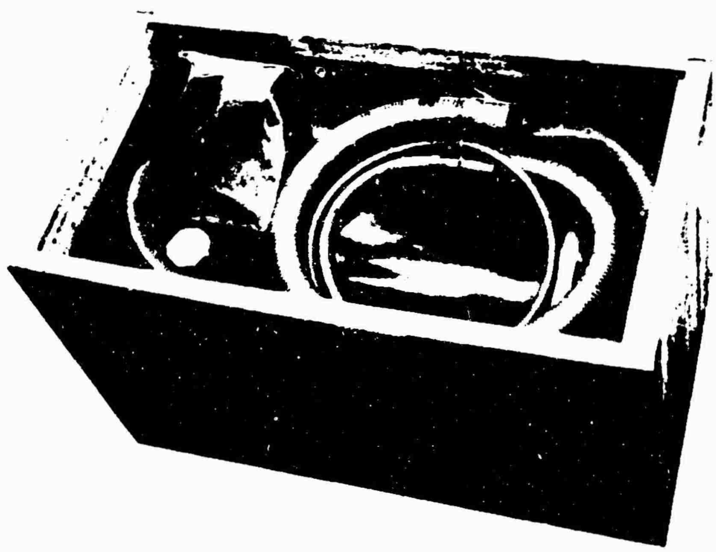


Figure 129. M2A2 Collective Protector Packed in Waterproofed Box

5. Packing.

See the M2 Collective Protector.

G. Protector, Collective, M3 (Standard).

1. Military Requirement.

A formal military requirement was established for the M3 Collective Protector when the unit was standardized.

2. Description.

The protector consisted essentially of a blower, driven by a 1/8-hp, 110-volt, 60-cycle, ac, single-phase electric motor, and a canister for removing war gases and smokes from air. It was approximately 18-in. wide, 19-in. deep, and 58-1/4-in. high, weighed 225 lb, and provided at least 50 cu ft/min of air. Major parts of the protector are shown in figures 130 and 131.

3. Operation.

The blower drew air from the atmosphere through the intake and forced this air through a 75-lb canister (Canister, Collective Protector, M2). The purified air reached the protected space by way of discharge elbow. Screens were attached to intake and discharge ends of the protector to keep out insects and animals. The power for the motor was derived from any available 110-volt, 60-cycle, ac source of electricity.

H. Protector, Collective, M4 (Substitute Standard).

1. Military Requirement.

There was a military requirement for a relatively inexpensive civilian collective protector.

2. Description.

A photograph of the M4 Collective Protector is shown in figure 132. The protector consisted of a rectangular base compartment 34-5/8-in. long, 27-1/2-in. wide and 41-in. high, the side walls and bottom of which were constructed of 18-gage sheet steel. On the top plate at the centerline of one side there was cut an aperture, 10-3/16-in. by 13-9/16-in., over which there was fitted a vertical director header column 33-3/4 in. high, the top of which was closed. The entire structure was made airtight by welded and bolted joints and the only openings were as follows: just above floor level on the front side there was emplaced a 12-3/16 by 4-3/16 in. opening to which the air inlet duct was connected by an airtight seal; about midway up one

side of the header column, there was an aperture 5 in. in diameter to which the airblast supply duct was connected and on the inside of the header column there was emplaced a counter-weighted damper that covered this last-mentioned opening; at the top of the header column rectangular openings 6 by 4 in. were cut into three of the side walls and it was through these that purified air was distributed to the chamber.

On the top plate of the container there was located a 1/4-hp electric gearhead motor with two shafts on both ends. One, the high-speed shaft, was connected to a fan inside the header column. The other, a low-speed shaft, was used for handcrank operation in case of motor failure. The weight of the unit was about 450 to 500 lb.

3. Operation.

Air was drawn into the air inlet above which was a dust filter consisting of a metal-screened frame 24-5/8 by 19-3/16 by 1-13/16 in. containing a glass fiber filling. After passing through the horizontal dust filter the air divided into four streams and passed through four frames each of which was approximately 24 by 25 by 6 in. and contained a 1-5/16 in. layer of charcoal and a 4-1/2 in. smoke filter pad of rock wool. These frames were placed in a vertical position. After passing through the frames the air was drawn through a horizontal fines filter and from there through the aperture in the top plate. The blower which draws the air through the canister was located above this aperture in the header column. To prevent drafts the header column distributed the air above the heads of the men in a shelter.[59]

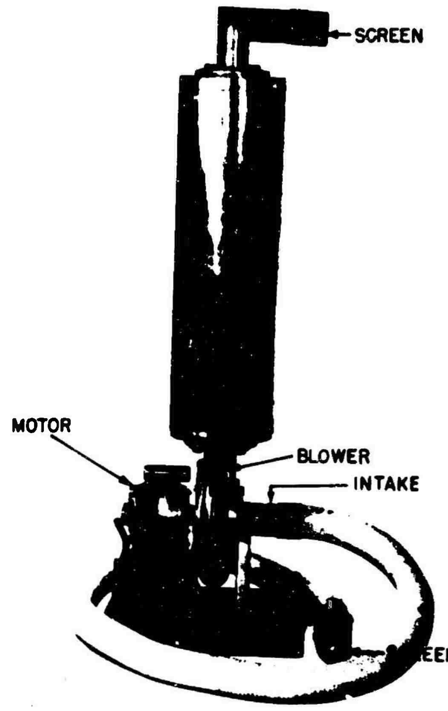


Figure 130. M3 Collective Protector

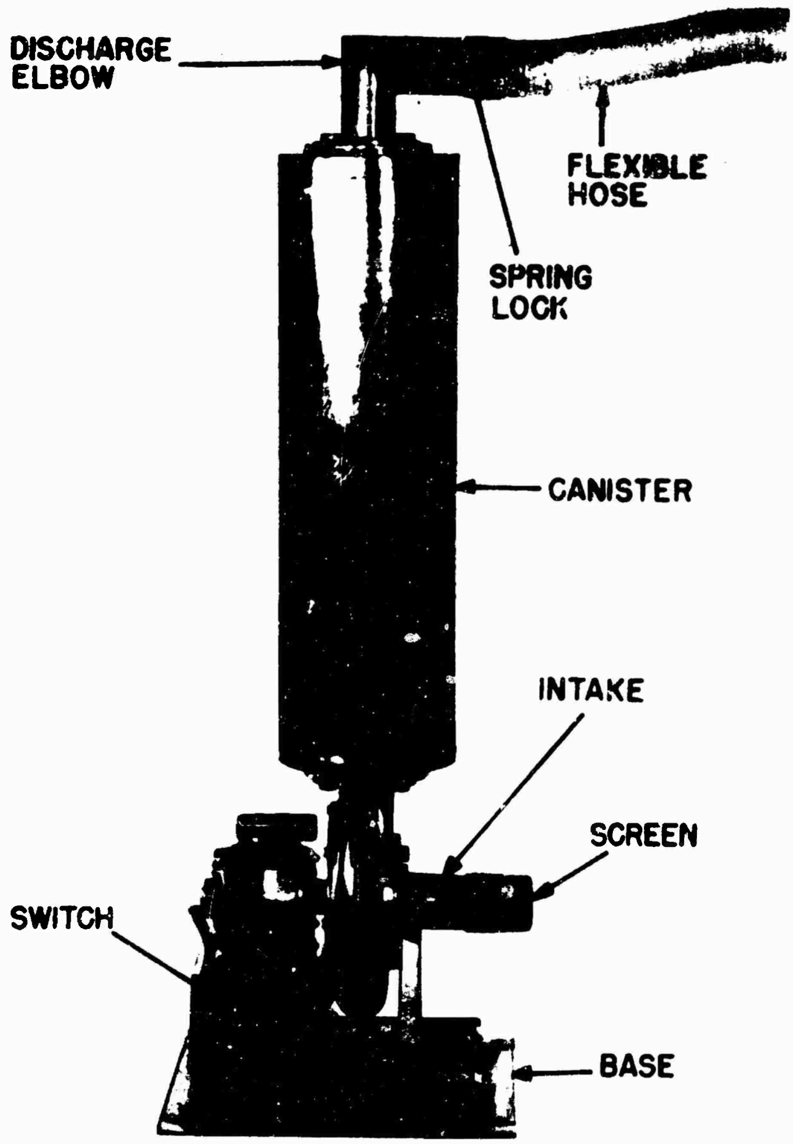


Figure 131. Assembling M3 Collective Protector

Figure 132. Civilian Collective Protector M4

4. Packaging.

None.

5. Packing.

The entire collective protector was packed in one shipping container. To reduce the sizes of the container needed, the crank handle, distribution header, and the airblast nozzles were fastened separately in the container. The container was constructed to insure acceptance by common or other carriers, for safe transportation, at the lowest rate, to the point of delivery.*

I. Canister, Collective Protector, M4A1 (Substitute Standard).

1. Military Requirement.

The military requirement was the same as for the M4 Collective Protector.

2. Description.

The M4A1 Canister was the base section of the M4 Collective Protector except that the top plate was not as heavily braced because there was no motor blower or header column and the outlet aperture was more centrally located.

3. Operation.

The operation of this unit was the same as that of the M4 Collective Protector. The M4A1 Canister was designed for use in multiple unit installation and not as a replacement for the M4 Collective Protector.[59]

4. Packaging.

None.

5. Packing.

The collective protector canister shall be packed in standard commercial containers so constructed as to insure safe delivery and warehousing.**

*CWS Specification 197-54-248 with Amendment No. 1.
**CWS Specification 197-54-250A, 26 Aug 1943.

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13. ABSTRACT

(U) This report on antigas collective protection equipment is one of a series of historical monographs. The decision to issue the report was made because of renewed interest in the subject. The report covers not only the Chemical Warfare Service's research and development in the area of antigas collective protection equipment during World Wars I and II, but also discusses domestic and foreign developments. Source materials were obtained principally from the Edgewood Arsenal Technical Library, Edgewood Arsenal, Maryland. In general, the monographs, when completed, will provide a history of CWS wartime research and development, focused particularly on the work done from 1 July 1940 to 31 December 1945.

14. KEYWORDS

Antigas collective protection	History	Smoke filter
Collective protectors	Fan design	Dust filter
Canister test methods	Canisters	Adsorbants
Air purifying equipment	Tank protectors	Humidifier
Shelter air requirements	Vehicle protectors	Dehumidifier
Air relief valve	Facepiece protector	Ventilated shelters
Air purification	Filter materials	

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